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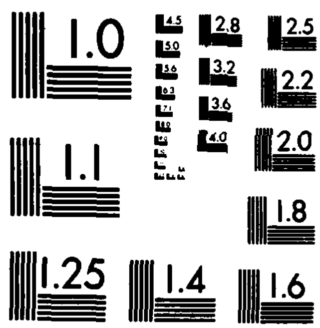
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METHODOLOGY FOR MEASURING THE EFFICIENT
USE OF AVAILABLE RESOURCES IN AIR FORCE
CIVIL ENGINEERING ORGANIZATIONS

THESIS

Marvin N. Fisher
First Lieutenant, USAF

AFIT/GEM/LSM/84S-8

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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The purpose of this Thesis ~~research effort~~ was to determine if a quantitative model of the efficient use of available resources could be developed for Base Level Civil Engineering organizations. Available resources included personnel, material supplies and vehicle resources and was limited to those resources used in the Operations Branch. The modeling technique used in this research effort was the Constrained Facet Analysis (CFA) which can evaluate an organization based on a set of multiple outputs and multiple inputs. The set of outputs and inputs were simultaneously evaluated to produce one effciency rating for each organization in the data set. The model also identified the relative importance of each output/input variable and identified the surplus variables causing the inefficient rating in the inefficient organizations. The analysis was accomplished by collecting data from the civil engineering organization within the Tactical Air Command. The data was analyzed using the CFA program at the Univ~~ersity~~ of Texas at Austin. The results illustrated that the efficient use of available resources could be modeled using the CFA technique. Originator-supplied keywords included: (40/473A)

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

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Marvin N. Fisher, B.S.

First Lieutenant, USAF

September 1984

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Abstract

The purpose of this research effort was to determine if a quantitative model of the efficient use of available resources could be developed for Base Level Civil Engineering organizations. Available resources included personnel, material supplies and vehicle resources and was limited to those resources used in the Operations Branch. The modeling technique used in this research effort was the Constrained Facet Analysis (CFA) which can evaluate an organization based on a set of multiple outputs and multiple inputs. The set of outputs and inputs were simultaneously evaluated to produce one effciency rating for each organization in the data set. The model also identified the relative importance of each output/input variable and identified the surplus variables causing the inefficient rating in the inefficient organizations. The analysis was accomplished by collecting data from the civil engineering organization within the Tactical Air Command. The data was analyzed using the CFA program at the University of Texas at Austin. The results illustrated that the efficient use of available resources could be modeled using the CFA technique.

METHODOLOGY FOR MEASURING
THE EFFICIENT USE OF AVAILABLE RESOURCES
IN AIR FORCE CIVIL ENGINEERING ORGANIZATIONS

I. Introduction

Overview

Research in the field of organizational effectiveness has rapidly grown in recent years. Increased economic constraints force organizations to look for more effective and efficient means of producing their goods and services. Productivity in operations will be the number one goal stressed by managers in the future (Bryne, 1978).

Even though organizational effectiveness is a relatively new field of study in organizational behavior, many organizational theorists have made an attempt to develop the criteria that describes effectiveness. Because of these many varied approaches, organizational effectiveness has become a nebulous term that is difficult to define. The development of meaningful, relevant data describing the performance of an organization often proves more difficult and costly than managers expect (Bryne, 1978). Xerox executive Vincent Bryne (1978) further points out that too often managers develop measures that provide them a "static snapshot" of the organization which, over time, may provide trend data, but does not identify cause-effect relationships.

Like many major corporations, military organizations have become more concerned with the effective utilization of resources. Pressure from the public sector to reduce federal budget deficits places an increased burden upon government officials. The Department of Defense (DOD) maintains the largest portion of controllable federal expenditures, therefore, the DOD becomes more susceptible to budget reductions. Former Assistant Secretary of Defense Frank Carlucci began the campaign to enhance organizational effectiveness by implementing several productivity improvement actions (Howell & Van Sickle, 1982). DOD Directive 5010.31 and DOD 5010.34 establish the foundation of the DOD Productivity Program. These guidelines instruct DOD managers to focus their attention on achieving maximum outputs within available resource levels and operating both efficiently and effectively (Howell & Van Sickle, 1982).

As stated earlier, measuring organizational effectiveness is a difficult task, but this task is more complex in a military organization since it is a non-profit organization. Anthony and Herzlinger (1980) identify a set of nine characteristics of a non-profit organization.

1. An absence of a profit measure.
2. Tendency to be service organizations.
3. Constraint on goals and strategies due to a lack of choice on where to do business.
4. Less dependent on clients for financial support.

5. Dominance of professionals in top management.

6. Line of responsibility is often unclear.

7 Chief executive officer does not have overall responsibility.

8. Importance of political influences.

9. A tradition of inadequate management controls.

The absence of a profit measure is a key factor in establishing criteria of effectiveness in military organizations. In a profit-oriented company, success is measured by the amount of profits an organization earns, and managers make decisions based on which alternative will produce the largest profit margin (Anthony & Herzlinger, 1980). Likewise, sales and credit suffer if a company is inefficient (Howell & Van Sickle, 1982).

Since military organizations are service-oriented, management decisions are made on the basis of providing the best possible service with the available resources, so the success of the organization is often hard to determine (Anthony & Herzlinger, 1980). Government managers do not have fast and specific feedback mechanisms like profit measures which detect inefficient operations (Howell & Van Sickle, 1982).

The Office of the Secretary of Defense (OSD) has established a six year program that will perform efficiency reviews of all military support activities (RPMA, 1983). The goal of this program is to increase productivity through

the accomplishment of each Service's mission in the most cost-effective manner, without decreasing mission effectiveness. The OSD has already projected a four percent manpower savings as a result of this review program. For Air Force manning alone, this equates to 800 slots per year for the next five years. Those support activities that can demonstrate the most efficient use of their resources will face the least manpower reductions. (RPMA, 1983)

The need for a set of criteria to measure organizational effectiveness has become apparent in objectives established by Air Force Civil Engineering directives. Major General Clifton D. Wright (1983), Director of Engineering and Services, sets forth in the Engineering and Services Strategic Plan the goal "to improve organizational structure, policies, regulations, and procedures to enable the Base Civil Engineer and Chief of Services to do their jobs more effectively." Air Force Civil Engineering faces real threats of continuing manpower reductions, contracting out of functions, and the possibility of a tri-service Real Property Maintenance Activity (RPMA) approach (RPMA, 1983).

The mission of base civil engineering maintenance management is to "provide the necessary assets and skilled personnel to prepare and sustain global installations as stationary platforms for the projection of aerospace power in peace and war" (AFR 85-10, 1975). According to AFR 85-1,

(1982), Resources and Work Force Management, the goal of civil engineering management is

> to provide an operational installation capable of supporting the mission, including the development and implementation of programs designed to improve the livability of the base community. Maintenance management procedures are important, because they provide the framework for an orderly process that matches available resources with requirements. Although the correct use of procedures can lead to successful programs, it is not the only measure of an effective BCE organization. Positive results in terms of mission and people supporting programs are the best measure of success.

The text of this regulation allows civil engineers to be flexible in the performance of their duties. Because the mission of civil engineering is service-oriented, developing measurment criteria for organizational effectiveness has become a challenging task for the civil engineering community.

Increased civil engineering effectiveness has been a key issue of directors of civil engineering since Major General Guy H. Goddard first addressed the issue in the early 1970's (Baumgartel & Johnson, 1979). Civil engineering spends 40-60% of a base's total operations and maintenance budget (McKnight & Parker, 1983). Since civil engineering accounts for such a large portion of the operations and maintenance expenditures, the emphasis on increased productivity creates the need for measurement criteria.

Statement of Problem

In response to an Air Staff thesis proposal, Capt. McKnight and Capt. Parker (1983) began the development of a model of base civil engineering organizational effectiveness. They defined the development of this model as a three stage process. Stage one defines the criteria or areas of importance. Stage two is the development of measures for these criteria, and stage three includes the validation and application of the model. McKnight and Parker successfully completed the first stage of this process by determining nine factors of organizational effectiveness of a base civil engineering squadron. (See Figure 1).

McKnight and Parker describe organizational effectiveness (OE) as a function of the nine factors that were determined by surveying wing, base and base civil engineering commanders at Continental United States (CONUS) installations. Their function does not determine how much each factor affects organizational effectiveness, only that a relationship exists (McKnight & Parker, 1983).

OE = f(F1, F2, F3, F4, F5, F6, F7, F8, F9) where:

F1 = Fire Protection
F2 = Leadership
F3 = Readiness
F4 = Resource Availability
F5 = Organizational Health
F6 = Program Mangement
F7 = Contract Management
F8 = Operations Workforce Performance
F9 = Customer Image

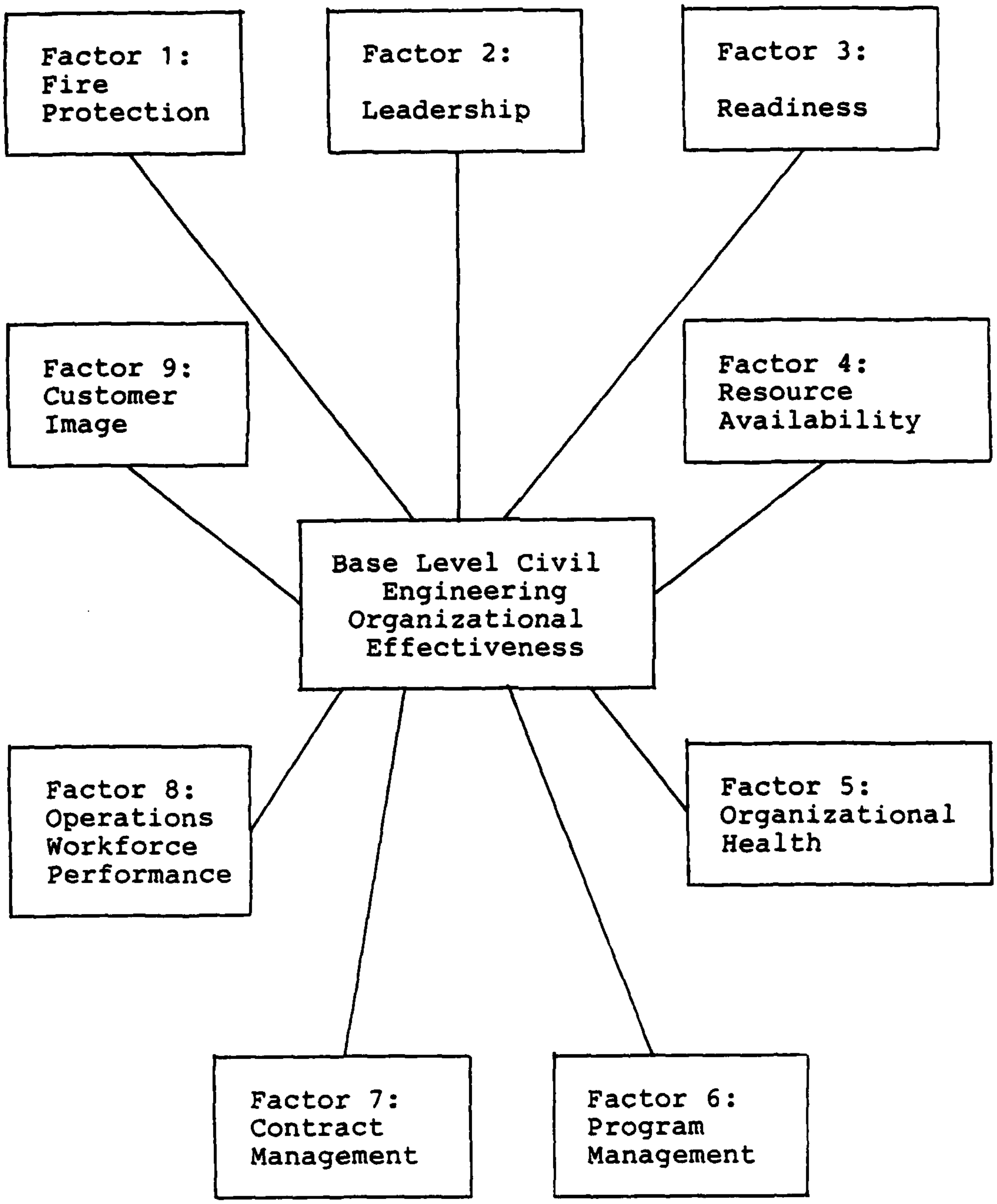


Figure 1. Factors of Effectiveness (McKnight & Parker, 1983)

The nine factors stated in their model were defined by 33 criteria specified as critical components to organizational effectiveness by the survey respondents. (See Table 1.1).

TABLE 1.1

Factors of the Functional Model of Effectiveness

Factor 1: Fire Protection

1. Fire Protection Capability
2. Fire Crash/Rescue Capability

Factor 2: Leadership

1. Supervision of Operations Workforce
2. Management of Engineers and Draftsmen
3. Leadership

Factor 3: Readiness

1. Readiness Capability

Factor 4: Resource Availability

1. Number of Personnel Assigned vs Authorized
2. Material Availability
3. Sufficient Number of Vehicles

Factor 5: Organizational Health

1. Commitment of Personnel
2. Organizational Morale
3. Cooperation between CE Branches
4. Retention of Personnel
5. Communication up and down the Chain of Command
6. Recognition

TABLE 1.1 Continued

Factor 6: Program Management

1. Management of the CE Budget
2. Emphasis on Energy Conservation
3. Quality of OJT Programs
4. Personnel and Vehicle Safety

Factor 7: Contract Management

1. Accuracy of Contract Work Descriptions
2. Identification of Maintenance and Repair Work by Contract
3. Accuracy of Engineering Design Program

Factor 8: Operations Workforce Performance

1. Maintenance of Military Family Housing
2. Utility System Operations
3. Workforce Productivity
4. Base Appearance
5. Weekly Schedule Compliance
6. Integrity of RMP Program
7. Airfield Maintenance

Factor 9: Customer Image

1. Public Relations Effort of CE
2. Professional Image of CE Customer Service Unit
3. Customer Satisfaction
4. Responsiveness

Reprinted from Development of an Organizational Effectiveness Model for Base Level Civil Engineering Organizations (McKnight & Parker, 1983)

The purpose of this research effort was to identify the variables that constitute resource availability (Factor 4) and develop a model that measures the efficient use of available resources in a base level civil engineering organization. By modeling the efficient use of available resources, this research effort will aid in determining the efficiency of civil engineering organizations, thus contributing to the goal of the OSD productivity improvement program. The use of available resources is one area in which civil engineering managers can improve performance without degrading mission effectiveness simply by being more efficient in the application of their available resources. This research effort established a standard set of measurement criteria and validated a model that determines the efficient use of available resources based on a set of measurement criteria.

Objectives of Research

The objective of this research effort was to continue the study initiated by McKnight and Parker in order to develop an organizational model for CONUS base level civil engineering units. This author will be completing one portion of the required research effort, but combined with the efforts of other researchers, the entire model may be completed and used as a mangement tool by civil engineering managers to evaluate and identify inefficient areas within their organization. At the time of this research, research

was also being conducted on the factors of leadership, fire protection, program management and contract management. The approach of this study was to review literature concerning the development of measurement standards of organizational effectiveness and determine an appropriate modeling technique to use for measuring the efficient use of available resources.

Research Questions

To achieve the research objective, the following research questions were answered:

1. Which variables describe a unit's available resources?

2. How will the variables be weighted?

3. Which variables significantly impact the efficient use of available resources?

4. Can tradeoffs and recommendations be found which allow inefficient organizations to improve their efficiency?

Scope

This research effort was limited to determining measurement criteria for CONUS Air Force installations. The study conducted by McKnight and Parker (1983) was limited to surveying CONUS installations, hence, research into the development of measurement criteria must also be limited to CONUS installations.

As stated earlier, the purpose of this research effort is to determine the criteria that constitute resource availability as a factor of organizational effectiveness. In order to narrow the scope of this project, the available resources to be analyzed was limited to those resources used in the Operations Branch of the Civil Engineering units. The Operations Branch is responsible for all the day-to-day maintenance and repair tasks of a civil engineering unit. Some minor construction projects are also accomplished. Approximately 80% of the civil engineering work force is in the Operations Branch. This research effort, therefore, focused on those resources controlled by civil engineering managers in their daily work function.

The model developed determined how efficient a civil engineering organization uses available resources. By improving efficiency, an organization can improve its productivity and effectiveness. The information gained by using an efficiency model will allows managers to reevaluate resource allocation in a logical manner and make appropriate adjustments without degrading organizational effectiveness.

Assumptions

This research effort was based on the following assumptions:

1. Resource availability is actually a factor of organizational effectiveness.

2. The mission of overseas installations differs from CONUS installations due to increased readiness requirements.

3. Base level civil engineering managers will be able to collect data that describes input and output criteria of available resources.

4. By increasing the efficient use of available resources, managers will be able to improve the productivity, and thus, the effectiveness of their organizations.

II. Literature Review

Introduction

This chapter reviews the current approaches to decscribing organizational effectiveness. Many theories have been developed to describe organizational effectiveness, but organizational theorists seem to agree on only one thing: that organizational effectiveness is multidimensional and the determinants of organizational effectiveness vary among organizations (Angle & Perry, 1981). This review compares existing theories on measurement criteria in order to establish a framework for determining the criteria of resource availability as a factor of organizational effectiveness. Frank Harrison (1978) describes current theories on organizational effectiveness by stating that

> There is no lack of criteria for assessing the performance of formal organizations; there is, however, a lack of general agreement as to which criteria are most valid and meaningful for use within a given organization.

Noted organizational theorist Richard M. Steers (1975) conducted a study on 17 models of organizational effectiveness and found that the different models used a diverse set of criteria to evaluate organizational effectiveness. (See Table 2.1). Steers thought that too many approaches take a macro approach to organizational

effectiveness, thus making measurement criteria difficult to determine and far too often useless as a management tool (Steers, 1975).

TABLE 2.1

Frequency of Occurrence of Evaluation Criteria

Criteria	Number of times mentioned
Adaptability/Flexibility	10
Productivity	6
Satisfaction	5
Profitability	3
Resource Aquisition	3
Abscence of Strain	2
Control over Environment	2
Development	2
Efficiency	2
Growth	2
Integration	2
Open Communications	2
Survival	2
Other	1

Reprinted from Problems in the Measurement of Organizational Effectiveness (Steers, 1975)

Resource management affects many of the criteria identified in the study conducted by Steers. Not only does it affect resource acquisition, it also plays a key role in the productivity, profitability, and efficiency of an organization. The management of available resources can be considered one of the most important factors of organizational effectiveness.

Budget reductions and constrained national resources make the need for the development of measurement criteria for organizational effectiveness even more evident in the federal government. In the study completed by McKnight and Parker (1983), resource availability was identified as the fourth most important factor in organizational effectiveness in civil engineering units. Although mission requirements are increasing, the supporting elements of money, material, and manpower are becoming more scarce (Thorne, 1980).

This chapter will review organizational theories to determine if resource availability can affect and help describe organizational effectiveness. It will also review current studies conducted on approaches to productivity and effectiveness of Air Force organizations and Air Force civil engineering units. Before discussing the current literature, several key terms need to be defined.

Definition of Terms

A distinction between efficiency, productivity, and effectiveness is necessary in any discussion of organizational effectiveness. The interrelationship between these terms varies among organizational theorists. As demonstrated in Steers' (1975) criteria study, productivity and efficiency have been identified in many approaches as key evaluation criteria for organizational effectiveness.

Most theorists agree on the definition of efficiency as the ratio of inputs to outputs (Angle & Perry, 1981; Anthony

& Herzlinger, 1980; Harrison, 1978; and Thorne, 1980). Using efficiency as an evaluation criteria is common in most taxonomies of the dimensions of organizational effectiveness (Angle & Perry, 1981; Steers, 1975). Efficiency has also been defined as the quantity factor of productivity (Thorne, 1980). Harrison (1978) identifies efficiency as a short-range factor that contributes to the short and long-range aspects of effectiveness. He makes a distinction between efficiency, doing things right, and effectiveness, doing the right things. For the purpose of this discussion, efficiency is defined as the amount of output per unit of input without regard to organizational goals and objectives.

The definition of productivity is not as clear as the definition of efficiency. Productivity has been defined along the lines of efficiency as the measure of output to some measure of input (Baumgartel & Johnson, 1979), others have defined productivity as the process where efficiency and effectiveness constitute productivity (Thorne, 1980).

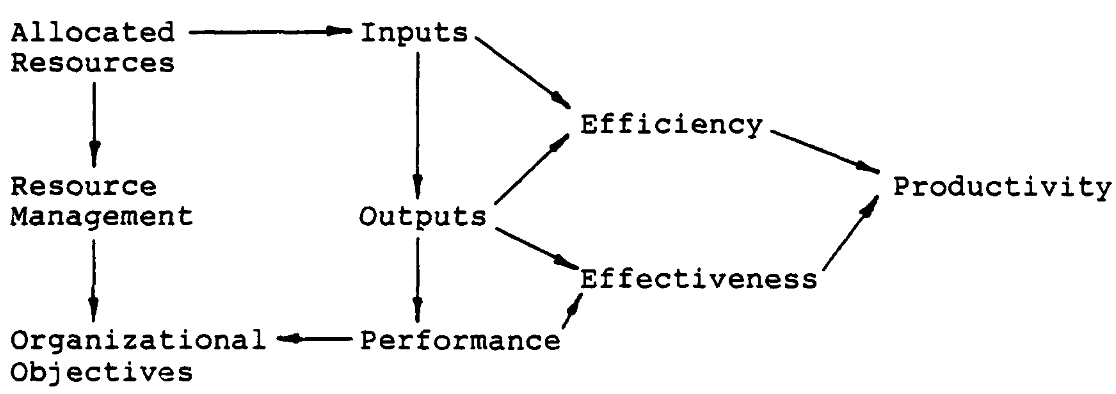


Figure 2. Components of Productivity (Thorne, 1980)

In the Department of Defense, measuring productivity is difficult because of the lack of performance measures. In the private sector, management decisions rely on business orientation toward revenues, returns on investment, and profit to measure efficiency and effectiveness (Thorne, 1980; Anthony & Herzlinger, 1980). Productivity is not easily measured in the public sector because 1) outputs are not always measurable in quantitative terms, and 2) multiple objectives preclude the use of a single measure (Thorne, 1980). As stated earlier, DOD organizations are service-oriented; hence, increased productivity relies upon cost reductions and maintaining the same level of service.

Although theorists differ in their definitin of productivity, an interrelationship between efficiency, productivity, and effectiveness does exist. Productivity is defined as the measure of input required to produce a desired measure of output. The key difference between efficiency and productivity is that productivity takes into account a desired level of output where efficiency is merely the ratio of output to input. Productivity is therefore, the link between efficiency and effectiveness.

Effectiveness is defined as the relationship between a unit's outputs and objectives (Anthony & Herzlinger, 1980). In other words, effectiveness is how well an organizational unit performs its job in respect to desired goals and objectives. Effectiveness can also be defined as the

capacity to pursue and reach operational objectives (Hitt & Middlemist, 1979). But like productivity, measuring effectivness is often a more difficult task because an organization's objectives may be quite general and/or nebulas in nature (Thorne, 1980). Effectiveness, therefore, is defined as the amount of output required to achieve organizational objectives. Increasing efficiency alone may not necessarily increase effectiveness, but by increasing efficiency to increase productivity will lead to increased effectiveness.

Measuring Organizational Effectiveness

Many attempts have been made to correctly identify the measurment criteria of organizational effectiveness. Steers (1975) developed a set of eight problem areas that must be addressed in the development of any measurement criteria.

1. Construct Validity - a) identify the domain of the relevant criteria and, b) determine the interrelationship between variables and how the exterman environment affects them.

2. Criterion Stability - criteria changes over time.

3. Time Perspective - what time frame is used to measure effectiveness?

4. Multiple Criteria - what is the relationship between criteria?

5. Precision of Measurement - does the model accurately and consistently quantify the criteria?

6. Generalizability - does the criteria apply to other organizations?

7. Theoretical Relevance - does the model contribute to our understanding?

8. Level of Analysis - at what level of the organization does the model evaluate effectiveness?

These problems exist in any measure of organizational effectiveness. The problem areas identified above demonstrate the complexity of measuring organizational effectiveness. Taking into account the external factors of an organization alone could be an endless task.

Early models of organizational effectiveness were one-dimensional in nature. These models are divided into three categories. The first category evaluated the performance of the organizational structure and included the Rational-Goal and Systems Resource approach. Category two deals with the performance of the organization's human resources. The Managerial Process and Organizational Development theories are the two major models of the human resources approach. The final category, which includes the Bargaining, Structural Functional, and Functional approaches, evaluates the impact of an organization's functions or activities on organizational effectiveness. (Cunningham, 1977)

Of the three categories, the management of available resources approach to organizational effectiveness falls in category three under the Bargaining approach. In this

approach, a decision-maker should allocate his resources to respond to the problems of the highest demand (Cunningham, 1977). An organization is considered effective if the maximum return is obtained from the distribution of resources. Managers should make resources available on the basis of the best possible payoff from the use of resources (Cunningham, 1977).

Effectiveness statements are typically evaluative and normative in nature and rarely describe the performance of an organization (Conlon & Connolly, 1980). Effectiveness criteria are measured against a set of standards/norms established by management to evaluate performance. Conlon and Connolly (1980) agree with Steers in respect to the nature of organizational effectiveness. They proposed a multiple evaluation approach which combined the "organizational goals" theorists' and "systems" theorists' views in order to view organizational constituencies instead of relying upon one single statement (Conlon & Connolly, 1980).

The resource management approach is prevelant in the systems resource approach developed by Yuchtman and Seashore. In their approach, an organization is considered effective if it has the ability "to exploit its environment in the acquisition of scarce and valued resources" (Conlon & Connolly, 1980). Making resources available for production purposes is the key to survival for an organization. The

most important management decisions deal with the acquisition of resources.

The acquisiton of needed resources is also identified in the four approach hierarchy defined by Kim Cameron (1980). His study developed four approaches to the evaluation of organizations:

1. How well an organization accomplishes its goals.

2. How well an organization acquires needed resources.

3. Are there smooth internal processes and operations in the organization?

4. How well an organization responds to the demands and expectations of any group or individual who has a stake in the organization.

Again, resource availability is defined as a critical aspect of organizational effectiveness. But according to Cameron (1980), organizations with separate levels of command, like military organizations (non-profit organizations), cannot use any of these approaches because of the characteristics of such organizations. He discusses several reasons why these approaches do not work for military organizations, including the lack of measurable outcomes, goals that are ill-defined and complex, and a widely differing criteria of success (Cameron, 1980).

Other recent studies suggest that a multivariate model of effectiveness is the most useful and relevant (Hitt & Middlemist, 1979). By combining the theories of Yuchtman,

Seashore, and Steers, guidelines for criteria development in an effectiveness measurement methodology can be determined. These guidelines, developed by Hit and Middlemist (1979), are as follows:

1. Criteria should be based on organizational goals and objectives.

2. Criteria should allow for comparative study of organizations that perform different functions or operate in different environments.

3. Other relevant criteria besides productivity criteria should be included.

4. Methodology should include both positive and negative effectiveness criteria.

5. A procedure for determining proper weightings of different criteria should be included.

6. The method for determining criteria should be applicable at different analytical levels.

7. The method and resulting criteria should allow for the uniqueness of the organization and/or unit.

The four approaches of Cameron are included in the underlying principles of these guidelines.

Organizational effectiveness has become a key issue to military leaders in recent years due to scarce resources and force reductions. The paradox of doing more with less has become a reality. The development of resurce management practices to increase productivity is prevelant in the DOD.

The purpose of the resource management function is to "assure that limited resources are utilized to their optimum level in support of specified missions" (Ciaccio, 1983). Resources also play a critical role in the determination of force readiness. DOD decision makers and readiness managers have few analytical tools available that relate readiness to resource-flow decisions (Paulson & Shishko, 1981). Resource availability, therefore, must be considered in any measure of organizational effectiveness.

As stated in Chapter I, the Department of Defense established a productivity program with the issuance of DOD Directive 5010.31 and DOD Instruction 5010.34. The Air Force Human Resources Laboratory (AFHRL) was assigned the duty of developing the Air Force productivity measurement system. Productivity was defined as the ratio of output to input with goals considered (Howell & Van Sickle, 1982). Working in conjunction with the Maryland Center for Productivity and Quality of Work Life, the following objectives were established: (Howell & Van Sickle, 1982)

1. To review and define productivity criteria.

2. To evaluate and classify efficiency and effectiveness measures.

3. To identify major classes of variables which impact productivity.

4. To develop a conceptual framework for productivity research.

5. To conduct a field test of the method for generating organization productivity criteria.

The Maryland Center Methodology produced productivity indicators that have been tested in weather, administration, and maintenance areas. Four key requirements for productivity measurement methods were developed from this research (Howell & Van Sickle, 1982). The requirements are:

1. Organizational goals must be identified.
2. Output must be quantifiable.
3. Input must be quantifiable.
4. The time period to be measured must be specified.

Working independently from AFHRL and the Maryland Center, Baumgartel and Johnson (1979) developed a productivity measurement model for Base level USAF civil enginering organizations using a network of performance indicators/input ratios. Like the Maryland Center study, their approach to productivity was based on four questions:

1. What output is to be measured?
2. What input is to be measured?
3. Which input-output comparisons are relevant to the organization?
4. How are comparison results interpreted?

According to Baumgartel and Johnson, and congruent with the definition stated earlier, productivity is determined by the ratio of outputs to inputs with organizational goals considered. The performance indicators in their model are

based upon the overall organizational objectives defined externally, by customer requirements and MAJCOM desired results, and internally through BCE desired results. Increasing productivity leads to increased organizational effectiveness. An essential element to productivity is the management of available resources as demonstrated by their model.

Framework for Resource Availability

Based on the studies of organizational effectiveness, it appears that the availabiltiy of resources is indeed a factor of organizational effectiveness. Several theorists used the resource approach as a single factor of effectiveness (Yuchtman & Seashore, Cameron and Cunningham), while others identified resource acquisition and management as one variable of a multivariant model (Steers, Baumgartel & Johnson, Conlon & Connolly, Hitt & Middlemist). In order to define resource availability as a factor of organizational effectiveness, the following guidelines were used in the measurement criteria development:

1. Determine and quantify the input and output criteria to be measured.

2. Base the criteria on defined organizations goals and objectives.

3. Criteria will allow comparison between civil engineering organizations.

4. Input-Output comparisons will be weighted according to their relevance to the organization.

5. The time period to be measured will be specified.

The nine-factor model of organizational effectiveness developed by McKnight and Parker (1983) established a firm foundation for further research. The model they developed follows many of the principles stated above. By combining their initial efforts with appropriate modeling techniques, a useful management tool was developed to improve organizational effectiveness based on the efficient use of available resources. The modeling techniques and methodology are discussed in a separate literature review in Chapter III.

III. Methodology

Overview

Measuring the efficient use of available resources in Air Force civil engineering organizations is a complex problem because of its multiple-input, mutiple output characteristic. Few analytical models can correctly identify inefficiencies within organizations because the models cannot compare multiple-inputs to multiple-outputs, therefore, losing information contained in the interaction of these variables. A new approach, the Constrained Facet Analysis (CFA) which takes into account the relationship of multiple inputs and outputs, has been developed by Bessent, Bessent, Clark and Elam (1983). Their model is an extension of the linear programming model called Data Envelopment Analysis (DEA) developed by Charnes, Cooper and Rhodes (1978).

The Constrained Facet Analysis model will be used in this research effort to measure the efficient use of available resources in civil engineering organizations. This chapter will first discuss the limitations of ratio analysis and linear regression techniques of measuring efficiency. Then, a brief description of the DEA model will be given along with the development of the CFA model.

Following the discussion of the CFA model will be the specification and identification of input and output

measures of available resources for civil engineering units. Finally, a data collection plan will be specified as well as criteria for evaluating the research questions to be answered by this research effort.

In order to achieve the research objective of defining one of the factors of the organizational model for CONUS base level civil engineering units, the following research questions must be answered:

1. Which variables describe a unit's available resources?

2. How will the variables be weighted?

3. Which variables significantly impact the efficient use of a unit's available resources?

4. Can tradeoffs and recommendations be found which allow inefficient organizations to improve their efficiency?

Limitations of Ratio Analysis

Ratio analysis is a popular method of comparing the performance of similar organizations. Ratio analysis is a simple *ex post facto* method of evaluating organizations by using many ratios to represent multiple input and output relationships. The most common ratio analysis typically uses several ratios, each of which is a single output measure divided by a single input measure. The ratios are then compared between similar organizations to determine which organization is more efficient, i.e., the one with the highest ratio of output to input. Ratio analysis does not

attempt to put together all the ratios into one aggregate measure of efficiency, therefore, the interaction between all the inputs and outputs is not taken into account. As a result, ratio analysis cannot accurately compare the performance of similar organizations that have multiple input and output measures, particularly when an organization ranks high on some measures and low on others. (Bessent, Bessent, Clark, 1982)

Ratios tend to be popular measures of performance because they are usually familiar to managers and can be easily calculated. The information obtained from these ratios is often misleading because each ratio provides only a partial measure of the multiple input-output relationship.

Ratios typically take one of the following forms (Bessent, Bessent, Clark, 1982):

1. Percentages (Assigned/Authorized)
2. Output/Input
3. Input/Output
4. Input/Input
5. Output/Output

In their working paper comparing DEA to statistical-econometrics and ratio analysis, Bessent, Bessent, and Clark give a good discussion and examples of the problems encountered with the use of ratios in the DEA model. The risks from using these ratios is basically the same; "percentages and ratios frequently fail to explicitly

represent the magnitudes of the outputs or inputs in the numerators and denominators of the ratios during DEA evaluation." They suggest that ratios should be broken down into their physical input/output components for the DEA/CFA evaluation and then after the analysis the ratios could be put back into ratio form for review by managers.

Limitations of Linear Regression

Another well-known method of evaluating the performance of an organization is linear regression. Regression equations develop a relationship of the single-output, multiple-input variety. Regression analysis produces a defined curve of the average relationship between the output and multiple inputs. Again, Bessent, Bessent, and Clark (1982) present a well-defined and illustrated discussion comparing regression to the DEA model. They point out three shortcomings when comparing DEA and regression results:

1. Regression estimates fail to identify the existence and degree of inefficiency in organizations.

2. Multiple outputs may contain interactions which are undetected by regressions performed on each output separately.

3. Regression estimates confound inefficient and efficient units. Better regression estimates are obtained using the efficient units only.

Since linear regression is based on the average relationship of all the observations, residuals (error

terms) can take on positive values if above the average and negative values if below the average. The efficiency frontier is determined by the average, therefore, the size and direction of the residuals are a misleading measure of the efficiency of the organization. The average is not the true efficiency frontier for a given set of observations.

The purpose of a regression equation is to predict the level of output given a set of inputs. Least squares regression can only take into account the relationship of the multiple-inputs on each output separately in the case of multiple-output organizations. Because only one output can be analyzed at a time, the interaction between outputs competing for the same resources (inputs) is neglected.

Another shortcoming of regression analysis occurs in the case of organizations operating at different levels of technology. Both organizations could receive the same amount of inputs but the organization with a higher level of technical efficiency would achieve a higher level of output. The difference in their expected output levels would be accounted for in the residual term as a random error when in reality the variance introduced is not random, but actually caused by the technological difference. The regression curve would thus lie between the two units and therefore would misrepresent both organizations.

Bessent, Bessent, and Clark found that by removing the inefficient organizations from the regression equation, the

R values increased and there was also an increase in the significance levels of the regression coefficients. One would expect a decrese in the R value and significance levels when the number of observations are decreased which decreases the residual degrees of freedom. In otherwords, more of the variability of the expected levels of output are being explained by fewer observation points.

Regression analysis techniques are inappropriate for establishing a frontier of efficiency for nonprofit organizations. The shortcomings of regression analysis have only been briefly discussed here. As stated, a more in-depth discussion along with examples can be found in the paper written by Bessent, Bessent, and Clark (1982).

Data Envelopment Analysis

The key shortcoming of both ratio analysis and least squares regression is that neither approach can simultaneously evaluate multile inputs and outputs when determining efficiency measures for an organization. The Data Envelopment Analysis (DEA) approach was developed by Charnes, Cooper and Rhodes (1978) to determine the efficiency of a decision making unit (DMU) relative to similar units. Their technique is able to evaluate the efficiency of a DMU, taking multiple-inputs and multiple-outpus into account simulataneously. The DEA model generates an efficiency rating for each organization using

external methods to identify the units that produce the highest level of outputs from the least amount of inputs.

Another significant characteristic of the DEA model is that it is able to compare the multiple-input, multiple-output measures without having them in a common scale or unit of measure. DEA is able to do this because it is comparing each unit to the same measures of other units that have similar levels of outputs and inputs and therefore, does not require commensurating input and output measures. This characteristic is extremely valuable in the case of non-profit organizations that cannot always measure their objectives monetarily.

The DEA model provides a single aggregate measure of DMU's efficiency. An efficiency measure is a ratio, therefore, the highest possible rating a unit could achieve would be 1.0 since it is being compared to the units with the greatest amount of output for the amount of inputs. All units are compared to locate the best ones and to use those units as the criterion for efficiency evaluations of the remaining units (Bessent, Bessent, 1980). A unit with an efficiency rating of 1.0 will have the best combination of outputs and inputs, and efficiency less than 1.0 would indicate a DMU is inefficient relative to the criterion units. The DEA model will assign the highest possible efficiency when rating an organization.

The DEA technique does not require that the input and output measures be weighted _a priori_. The DEA model will assign weights, called multipliers, to the input and output measures, and these multipliers are derived empirically from the data used to generate the efficiency rating. These multipliers assigned to the inputs and outputs can then be used to locate sources of inefficiency within a DMU and tradeoffs that can be made to increase the efficiency rating of the DMU (Bessent, Bessent, Kennington, and Reagan, 1982). The multipliers indicate the possible shortages in output levels and/or averages of input levels.

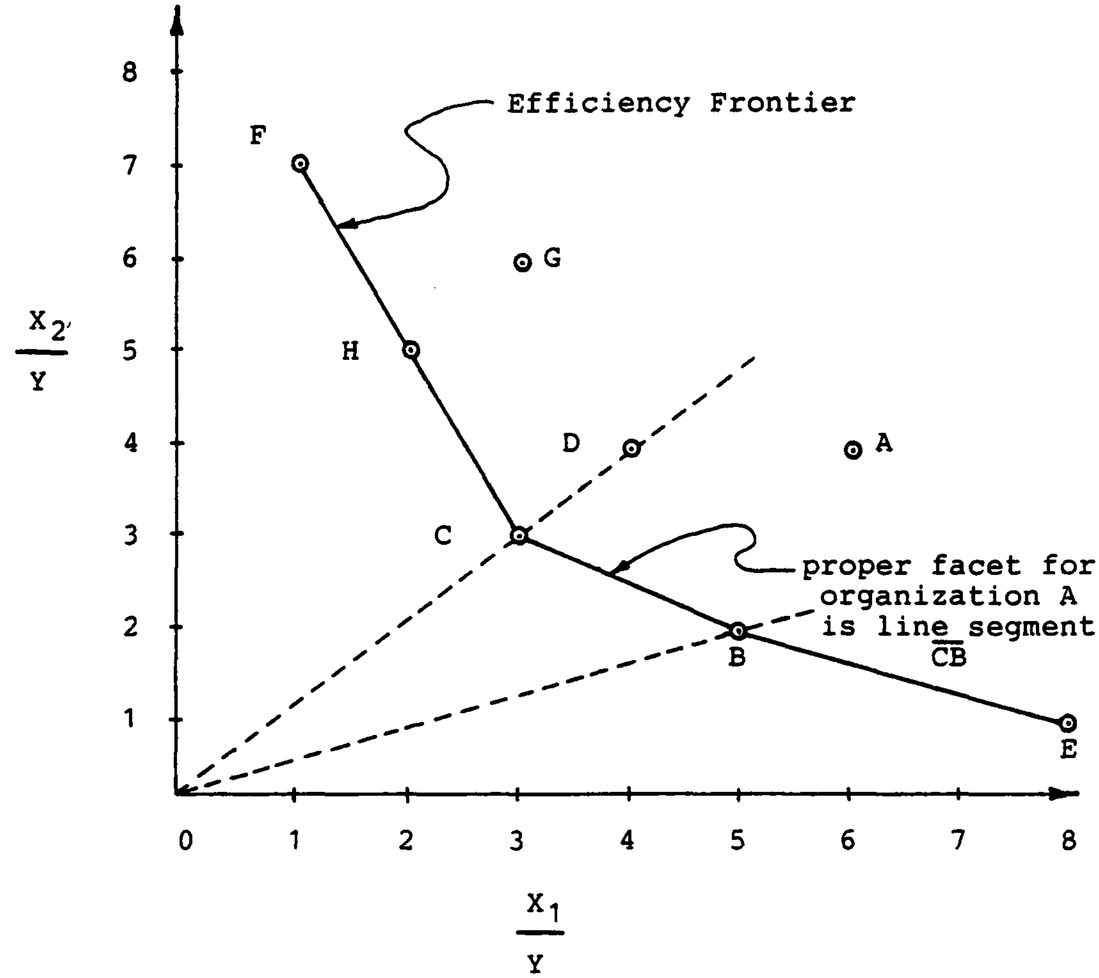
Constrained Facet Analysis

The Data Envelopment Analysis model brought about a significant improvement in the evaluation of the performance of organizations, but DEA had several limitations. Though DEA was effective in classifying DMU's as either efficient or inefficient, relative to a neighborhood of units with the greatest amount of outputs for inputs, DEA is limited in its ability to provide planning information (Bessent, Bessent, Clark, and Elam, 1983). As a result, a new approach for computing efficiency, called Constrained Facet Analysis (CFA) was developed by Bessent, Bessent, Clark, and Elam at the University of Texas at Austin.

The CFA model is an extensin of the DEA model. Like DEA, Constrained Facet Analysis is a linear programming

model that determines the relative efficiency of a DMU compared to other operating units with similar levels of inputs and outputs. The CFA model first identifies the efficiency frontier made up of those units with the highest level of outputs for their given level of inputs and assigns an efficiency rating to those units which are inefficient relative to the frontier units. The frontier units receive an efficiency rating of 1.0. Those units which are inefficient are then compared to only those units on the efficiency frontier with similar mixes of inputs and outputs. That portion of the frontier identified for comparison is called the "facet". A simple case can be illustrated using two input measures, and one output measure for eight organizations being compared. The proper facet for Unit A is identified in Figure 3. (Bessent, Bessent, Clark, and Elam, 1983)

The CFA model goes through an iterative process where it identifies the proper facet for a unit, assigning values for the unit's efficiency rating and multipliers after each iteration. The final iteration establishes a lower bound efficiency for the inefficient unit using only those units in a nearby frontier facet, units which have similar mixes of inputs and outputs. It must be noted here that the values for the efficiency rating and multipliers for a given unit after the first iteration of CFA will equal the values that DEA would assign the same unit.



where:

$\frac{X_1}{Y}$: the ratio of input one to output Y

$\frac{X_2}{Y}$: the ratio of input two to output Y

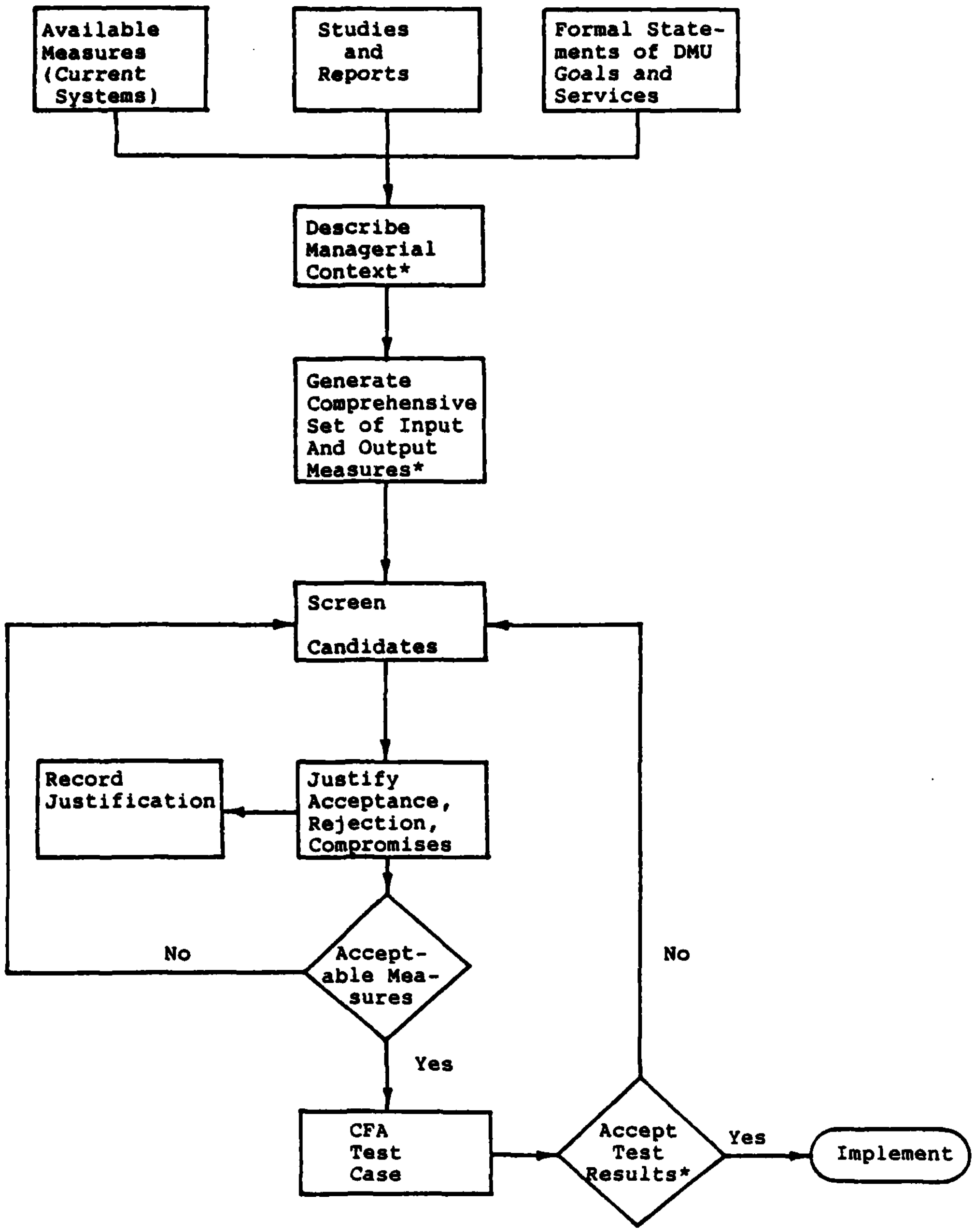
Figure 3. Facet Identification

Constrained Facet Analysis goes through this iterative process to find a set of comparison units that have similar mixes of inputs and outputs so that meaningful information can be gained for the inefficient unit. After the final iteration, managers of the inefficient unit will be able to compare possible tradeoffs to units that are similar to their own. By comparing an inefficient unit to only those units similar to that unit, the value of the information will be enhanced. (See Appendix A for CFA model representation.)

Specifying Input and Output Measures

The most important step in analyzing the efficiency of an organization is the specification of input and output measures. Establishing the input and output measures will determine the success of the efficiency model. Bessent, Bessent, and Clark (1982) provide a procedure for specifying inputs and outputs for DEA or the CFA model. Figure 4 provides a schematic of this specification process.

The input and output measures to be used in the efficiency analysis begin with the description of the managerial context. The managerial context is described by using the formal statements of the goals and services provided by the DMU, available measures used in the current performance measurement system, and other relevant reports and studies that may produce or identify potentially useful measures that are not currently being used. All pertinent



* These Activities accomplished by CFA specialists in concert with the managers and analysts responsible for monitoring and controlling DMU's.

Reprinted from <u>Specification of Inputs and Outputs in Data Envelopment Analysis (DEA)</u> (Bessent, Bessent, and Clark, June 1982)

Figure 4. Specification of Inputs and Outputs

performance measures should be identified. The selected inputs and outputs should form a complete representation of the DMU's operation.

Following the description of the managerial context, a comprehensive set of input and output measures must be generated based on the managerial context. This initial list should include all possible candidates. A candidate measure should not be eliminated unless the information is already contained in other mesures. The following guidelines should be followed (Bessent, Bessent, and Clark; 1982):

1. Outputs represent important DMU goals.

2. All measures apply to all DMUs being considered and exist in non-zero amounts.

3. Inputs represent all resources used by the units towards attainment of outputs.

4. Changes in inputs will result in a corresponding change in outputs, i.e., an increase in an input results in an increase in output.

5. The magnitude of physical input/output quantities are represented.

6. The quality of inputs and outputs are represented.

All possible input and output measures must be considered because of the problems that may arise if a critical input or output is eliminated from the model.

> If one eliminates (overlooks) either an output or an input, there is a significant risk of misclassification (wrong frontier), distorted neighborhoods, and erroneous slack conditions. Elimination of an output can cause unit misclassifications and incorrect slack conditions in _inputs_. Elimination on an input also causes misclassifications, but the erroneous slack conditions it generates will appear in the _outputs_. (Bessent, Bessent, and Clark, 1982)

Surplus variables are the multipliers identified in inefficient units by the DEA/CFA process. Erroneous surplus variables discredit the value of information produced by the DEA/CFA model.

Once a list of all possible inputs and output measures has been generated, the list of candidates must be screened to justify the acceptance or rejection of each measure. This is a critical step in the input/output selection process. The entire process cannot be considered complete until:

1. The list of input and output measures form a reasonable representation of the key efficiency variables for the DMU.

2. The input/output set chosen forms a realistic representation of the DMU's operation.

It may be necessary to use surrogate measures in order to capture a complete representation of the DMU's operation. Anthony and Herzlinger (1980) identify three measurement categories in which output measures can be classified: 1) result measures, 2) process measures, and 3) social indicators. Result measures attempt to express output in

terms related to the DMU's objectives. Ideally, both the objective and output measure can be expressed in the same measurable terms. When this relationship does not exist, then the accomplishment of the objective must be represented by an output measure that most closely represents the objective. Such a measure is called a surrogate. A surrogate results measure is an "ends-oriented" measure.

A process measure of a DMU's output is a "means-oriented" indicator. A "means-oriented" indicator measures what a DMU does in order to help achieve the organizations' objectives. This type of output measure is the easiest to interpret because there is a close causal relationship between inputs and process measures. They can only be used to measure efficiency within a DMU, but not effectiveness.

Social indicators are valuable in the measurement of a DMU's effectiveness, but does not apply to the DEA/CFA efficiency model. Few social indicators can be related to a single organization and are often nebulous and difficult to obtain, therefore will be excluded from consideration in modeling the efficient use of available resources within a civil engineering oranization.

Once an acceptable set of measures has been established, the DEA/CFA model must be tested to demonstrate the value of information. If an acceptable set of measures cannot be established, or if acceptable test results are not

achieved, then more analysis must be conducted to develop input and output measure candidates that more successfully measure the efficiency of a DMU. If acceptable test results are obtained, then the set of input/output measure should be implemented and the DEA/CFA program continued.

Identifying Input and Output Measures of Available Resources

The input and output measures for the efficient use of available resources can now be identified using the guidelines established in the preceeding discussion. Efficiency measurement is new to the civil engineering career field. Resource managers do use many performance indicators in their day-to-day operation but never before have efficiency measures been identified as such. The managerial context to be defined in this efficiency model will be the measure of resource availability in the accomplishment of the Operations Branch support of the civil engineering mission. The Operations Branch is, therefore, the DMU to be evaluated by the CFA model.

As stated earlier, the mission of base civil engineering maintenance management is to "provide the necessary assets and skilled personnel to prepare and sustain global installations as stationary platforms for the projection of aerospace power" (AFR 85-10, 1975). The Operations Branch supports this mission in the maintenance and repair of base facilities. The objective of the civil engineering unit is broadly defined in AFR 85-1 (1982),

Resources and Work Force Management, as providing engineering support for the base mission. The Operations Branch will be evaluated in the performance of its objective to support the base in the completion of all facets of maintenance and repair of base facilities using available resource measures. Current performance measures have been adapted to input and output measures and incorporated in the efficiency analysis.

Following is a comprehensive list of candidate input and output measures for the efficient use of available resources. This list was generated from past operational experience of the author and validated by a group of experienced civil engineering managers attending an Operations Management Applications Course at the Air Force Institute of Technology, School of Civil Engineering (February, 1984).

Outputs Selected:

Output 1: Number of Command Interest (CI) Work Orders (WO) completed.

A work order (as defined in AFR 85-1) accomplished in support of a special interest project. One that is given priority over other work orders due to the interest of the wing, base or civil engineering commanders. Result measure.

Output 2: Number of Routine Work Orders completed.

A work order that was processed in a normal sequence and procedure as defined by AFR 85-1. Result measure.

Output 3: Number of Emergency Job Orders completed.

A job order as defined by AFR 85-1. Result measure.

Output 4: Number of Urgent Job Orders completed.

A job order as defined by AFR 85-1. Result measure.

Output 5: Number of Routine Job Orders completed.

A job order as defined by AFR 85-1. Result measure.

Output 6: Recurring Maintenance Program Manhours completed.

Measures the amount of labor resources devoted to the recurring work program as described in AFR 85-1. Identifies resources not used for Work or Job Orders. Process measure.

Output 7: Utility Operations Manhours completed.

Measures the amount of labor resources devoted to utility operations. Identifies resources not used in accomplishing work orders or job orders. Process measure.

Output 8: **Indirect Manhours.**

Measures the amount of labor resources diverted from accomplishing maintenance and repair objectives. A surrogate measure of labor and resources used in accomplishing tasks not related to objectives. Indirect manhours include manhours used in training, vehicle and shop clean-up, etc. ... (See AFR 85-1 for complete definition.) Since manhours is also an input measure, indirect manhours is a process measure.

Output 9: **Average cost of Command Interest Work Orders.**

A process measure of the amount of resources used in accomplishing maintenance,repair and minor construction objectives. Labor and material costs are included in this output. The average cost of CI work orders can be viewed as a surrogate measure of output. The average cost of CI work orders must be included because of the wide range of scope that a work order can cover. A base that does only several very large CI work orders would look inefficient to a base that does many, very small work orders when

only the number of CI work orders is used as an output measure.

Output 10: Average cost of Routine Work Orders.

As in the case of the CI work orders, this output must be included as a surrogate measure of resources used in accomplishing maintenance and repair objectives. Average cost of routine work orders in a process measure that includes both labor and supply costs.

Supply Inputs Selected:

Input 1: Bench Stock Fill Rate.

This fill rate is normally determined by dividing the number of bench stock bins with at least one item in the bin by the total number of bins. This measure is currently used by many organizations to determine the availability of supplies for doing job orders. A bench stock is the civil engineering designation for a hardware store. Craftsmen can go directly to bench stock supplies to get materials to accomplish a job order without having to order supplies through Material Control.

Input 2: Number of Bench Stock line items available.

This measure is determined by counting the number of bench stock bins with at least one item in the bin. The number of bench stock line items measures the quantity of supplies available through bench stock. Bench stock fill rate captures the quality of the material stockage by measuring the percentage of supplies available. Both measures are required to describe the bench stock supply availability.

Input 3: Number of Residual items.

A residual item is a supply item that was purchased to accomplish a work order or job order that was later cancelled, or had excess materials. Since the supply item was already purchased, the item is placed in a residual holding area to be used to accomplish a future work order or job order if the need arises. Typically, the item is held for a period of six months. If it is not used in that time, the item will be salvaged. If a work order or job order requires a part already on hand in the residual area, then the item can be used

against that requirement. This input measures another available supply resource for accomplishing work orders and job orders.

Input 4: 1 / Material Lead Time.

Material lead time measures how quickly supply items are procured through the material control supply system. The lower the material lead time, the faster supply items are received. The reciprocal of material lead time is used as an input measure to establish the relationship of increased input causing an increase in output. If a unit lowers its material lead time, it will be able to generate more supply resources, hence, should be able to produce greater output levels.

Input 5: Number of Work Requests received.

This measure is one indicator of the workload for the Operations Branch. Work Requests (AF Form 332) are submitted to civil engineering by customers requesting work to be done in their facility. Once a work request is approved, it becomes a work order or job order. Work requests are used as the input measure instead of approved

work orders because every work request must be processed whether it is approved or disapproved.

Input 6: Number of Command Interest Work Orders received.

Since a Command Interest work request carries top priority, it is not necessary to count Command Interest work requests since they will all be approved, therefore, the number of Command Interest work orders received is used as the input measure.

Input 7: Number of Emergency Job Orders received.

As defined in AFR 85-1. This input is another indicator of the workload for the Operations Branch.

Input 8: Number of Urgent Job Orders received.

Same as Input 7.

Input 9: Number of Routine Job Orders received.

Same as Input 7.

Input 10: Number of material completed Work Orders in the Material Control Holding Area.

A material complete work order is one that has been processed by Material Control and all parts have been received. This input measures the amount of supply resources that are ready to be used to complete a work

order once labor manhours become available. Material complete work orders also give one indicationof the backlog of work to be completed.

<u>Input 11</u>: <u>Number of material complete Job Orders in the Material Control Holding Area.</u>

Same as Input 10.

<u>Input 12</u>: <u>Number of Work Orders meeting the Required Delivery Date.</u>

When supplies for a work order are ordered through Material Control, a Required Delivery Date (RDD) is put on the order. The number of work orders meeting their RDD indicates the responsiveness of the material control supply system.

<u>Input 13</u>: <u>Number of Job Orders meeting the Required Delivery Date.</u>

Same as Input 12.

<u>Input 14</u>: <u>Number of personnel assigned to Material Control.</u>

This input deals with personnel resources but has been put under the supply inputs because it measures the amount of labor resources devoted to supply requisitions. The number of personnel assigned to

Material Control is an indication of the amount of supply orders being processed.

Input 15: Ratio of personnel assigned to authorized in Material Control.

The number of personnel authorized in the Material Control section is determined by the Unit Manpower Document (UMD). The ratio of assigned to authorized measures the manning strength in Material Control.

Vehicle and Equipment Inputs Selected:

Input 16: Number of vehicles assigned.

This input measures the size of the vehicle fleet.

Input 17: Ratio of vehicles assigned to authorized.

The ratio of vehicles assigned to authorized measures the strength of the vehicle fleet.

Input 18: Vehicle In Commission (VIC) Rate.

The VIC rate is computed by the Transportation Squadron which performs the maintenance and repair of civil engineering vehicles. This input measures the amount of vehicles that are operational.

Input 19: Number of Taxi Vehicles.

AFR 85-1 requires civil engineering squadrons to operate a taxi service. The

taxi service is controlled by the Service Call Unit. Taxis are dispatched to transport craftsmen between job sites and shop locations. The number of taxi vehicles measures the size of the taxi service available.

Input 20: Number of taxi runs.

This measure indicates how much the taxi service is used by craftsmen to get from job site to job site.

Input 21: 1 / Average wait time for taxi.

The wait time for a taxi is determined by how long a craftsman must wait for the taxi to arrive once he has placed a call to the Service Call Unit requesting the taxi service. This input measures the responsiveness of the taxi service. The reciprocal of average wait time is used so that a decrease in the wait time will relate to an increase of this input (more responsive). Increased input should produce an increase in outputs because craftsmen would be spending less idle time and, hence, would have more time available to complete work requirements.

Input 22: 1 / Average age of vehicles.

The age of the vehicle fleet is an indication of the quality of the vehicle fleet. The reciprocal is used again here to establish a relationship of increased inputs causing an increase in outputs.

Input 23: 1 / Average number of miles per vehicle.

This input also measures the quality of the vehicle fleet. The reciprocal is used for the same reason as in Input 22.

Input 24: 1 / Number of vehicles on recall status.

When inspection teams, visiting distinguished guests or training exercises occur on an Air Force base, vehicles are recalled from lower priority organizations to be used by higher priority organizations. Civil engineering is one of the organizations that loses vehicles during recall exercises. The number of vehicles on recall status measures the amount of vehicle resources lost during recall exercises. The reciprocal measure is used because fewer vehicles on recall status will increase this input measure.

Input 25: Number of tool boxes assigned.

This input is an equipment measure that

indicates the amount of tools available for use by craftsmen.

Input 26: Ratio of number of tool boxes assigned to authorized.

The ratio of tool boxes assigned to authorized indicates how many craftsmen who are authorized a tool box, actually have one for their own use. The higher this ratio, the fewer the craftsmen that have to share tool resources.

Input 27: Number of tool boxes over 90% filled.

A tool box is considered 90% filled if that amount of the authorized tools are present in the box. This input measures the quality of tool boxes.

Input 28: Number of Privately Owned Vehicles (POV) authorized.

Some organizations allow craftsmen to drive their own vehicles between shop locations and job sites. The craftsmen are then reimbursed for their operating expenses. Organizations that authorize POV use will have more vehicle resources available than if they did not authorize POV use.

Personnel Inputs Selected:

Input 29: Number of military skill levels filled.

Each military position in the Operations Branch has an authorized skill level. The skill level of a position is the measure of expertise required for that position. Individuals can be assigned to a position with a lower skill level than that authorized skill level. The number of skill levels filled is a measure of the number of assigned personnel that have at least the required skill level for that position as indicated by the authorized skill level in the UMD. This input is a measure of the quality of the workforce.

Input 30: Number of military positions with correct grade filled.

Like skill level requirements, each military position has an authorized grade requirement in the UMD. The number of positions with at least the correct grade assigned to the positin indicates the experience level of the workforce. It is another indication of the quality of the workforce assigned to the positions in the Operations Branch.

Input 31: Total available manhours.

This input measures the amount of labor resources available for use in completing work requirements.

Input 32: Number of civilians assigned.

Civil engineering organizations hire a lot of civilian employees. This input measures the size of the civilian workforce.

Input 33: Ratio of civilians assigned to authorized.

T is input ratio measures the strengh of the civilian workforce.

Input 34: Number of military assigned.

This input measures the size of the military workforce within the Operations Branch.

Input 35: Ratio of military assigned to authorized.

The ratio of military assigned to authorized measures the strength of the military workforce.

Input 36: Ratio of military assigned to civilians assigned.

This input measures the relative size of the military workforce to the civilian workforce. This input measure may have to be reversed if the analysis of the data proves that a lower military workforce is more efficient.

Data Population

The Constrained Facet Analysis model has a requirement for the number of observations necessary to establish an efficiency frontier. The number of observations required is based on the number of output measures (m) and the number of input measures (n). The minimum number of observations required is 2(m+n).

From the comprehensive list of output and input measures for resource availability, a total of 36 inputs and 10 outputs were selected as possible candidates. In order to correctly measure the efficiency of a unit's resource availability, a total of 2(10 + 36) = 92 observations would be required if all inputs and outputs were used in the efficiency model.

The population for this research effort is the Tactical Air Command (TAC) bases. There are a total of 18 TAC bases in the CONUS. By collecting data from each base over a three month time frame, a total of 54 observations were generated. Fifty-four observations allowd the CFA model to use a maximum of 27 input/output measures in the determination of the efficient use of available resources. The input and output measures used were taken from the candidate list of measures previously identified. The final list of input and output measures were approved by the HQ/TAC Civil Enginering staff assisting with the collection

of the data. Appendix B lists the 18 bases in the Tactical Air Command.

TAC was chosen as the population for this research effort for two reasons. First, one command was chosen instead of using observations from all Air Force installations in the CONUS to reduce the variability caused by different major commands having different missions and aircraft. By using only one command, the mission of the installation should have had a similar effect on the civil engineering organizations in the population. Eliminating this variability improved the ability to compare the different organizations.

The second reason for using TAC bases as the population was that collecting the data for these bases was simplified because of the Work Information Management System (WIMS) in use at TAC Headquarters. The WIMS has been in use at TAC for several years. Much of the data required from each base was already being processed and stored in the memory files of the TAC system. It was possible to collect the majority of the data for this research effort directly from the memory files of the WIMS.

Criteria for Evaluating Research Questions

The CFA model has been validated and proved to be a valuable management tool for school administrators in the Texas School Districts. The information provided by the CFA model has helped identify the inefficient units and the

inputs/outputs that were contributing to the inefficient ratings. The purpose of the research effort was to find out if the CFA model can identify inefficient use of available resources in civil engineering organizations. More specifically, the purpose of this research effort was to provide information to the managers of the Operations Branch on how they can more efficiently use their labor, vehicles, equipment, and supply resources to accomplish their objective of performing maintenance and repair of base facilities.

The data collected from TAC bases was analyzed to answer the research questions as stated in previous sections. The CFA model helped identify which variables have the greatest effect on the efficient use of available resources.

The variables considered to be inputs and outputs were selected by the HQ/TAC/DE staff. The weights assigned to the inputs and outputs, as already stated, were determined by the CFA model when it assigned multiplier values to the inputs and outputs. The CFA model was developed to take into account the interactions between variables. The significance of each output and input variable was determined by the CFA model and was unique for each organization.

Finally, the purpose of the CFA model was to identify inefficient units and their surplus input quantities or

output shortages. The surpluses or shortages were the areas that the inefficient units should concentrate on improving. It was hoped that results of the CFA model would prove to be a valuable tool to civil engineering managers by identifying the inefficient use of available resources. It must be stressed that this model is a management tool, for use at both the major command (MAJCOM) and base level, that provides information to managers on how they are using their available resources in comparison with other similar organizations. The manager will still be responsible for analyzing the information and determining the appropriate actions necessary to improve the efficiency and effectiveness of his organization.

IV. Selection of Output and Input Measures and Data Collection

Introduction

This chapter presents a description of the final selection of output and input measures for modeling the efficient use of available resources in a civil engineering unit. The Tactical Air Command Civil Engineering Staff (HQ TAC/DE) was the final selection authority for the outuput and input measures. This was necessary in order to obtain approval of using the TAC bases as the data population. The HQ TAC/DE personnel collected and screened the data for the selected output and input measures before forwarding the data.

The output and input measures selected were based on the judgement of the HQ TAC/DE personnel. The measures selected were those measures that best described the available resources of a civil engineering unit at the TAC bases. Several measures had to be refined so that data could be collected and some candidate measures were eliminated due to the nature of TAC operating procedures. The final set of measures is a comprehensive list of 8 output measures and 16 input measures which best describes the available resources in a civil engineering unit.

Outputs Selected

The output measures selected for the efficiency model was a revised set of measures taken from the list of candidate measures described in Chapter III. HQ TAC/DEMG collects data on in-house direct and indirect manhours used at each TAC basse. The HQ TAC/DEMG staff believed that this data best described the output for the civil engineering units. The manhour data is broken down into eight measures:

TABLE 4.1

Output Measures Selected

Output:	Manhours for:
1	Minor Construction Work Orders completed
2	Other Work Orders completed
3	Emergency Job Orders completed
4	Urgent Job Orders completed
5	Routine Job Orders completed
6	Recurring Work completed
7	Utility Operations
8	Indirect hours

The data for these output measures could easily be collected from the TAC bases on a month to month basis. These eight output measures describe the output of a civil engineering unit as a process, not in terms of results and,

therefore, are actually surrogate measures of output. It was felt that the data on the candidate set of output measures would not be available since it is not a requirement to collect that data at TAC bases. The decision was made to substitute the eight measures of manhour use as the output measures for the efficiency model.

Inputs Selected

The final list of input measures selected was a set of measures developed by eliminating and combining the input measures from the candidate set of measures described in Chapter III. The candidate list of input measures was developed without taking into account any particular command's operating procedures. Several of the candidate input measures were eliminated because of the characteristic operating procedures of the TAC.

The input measure on Bench Stock Fill rate is not applicable to the majority of the TAC bases. Sixteen of the eighteen bases are under Contract Operated Civil Engineering Supply Store (COCESS) procedures and do not collect data on fill rates. The contractor is required to maintain stock levels as specified in the contract.

Data on material lead time and required delivery dates is not collected at TAC bases. The HQ TAC/DEMG staff believed that this information would not be available at the base level and therefore, eliminated the input measures requiring that data.

Several of the candidate input measures do not fall under the responsibility of the Civil Engineering Unit at TAC bases. The Transportation Squadron is responsible for all of the base taxi service and the Base Supply Tool Control is responsible for the control of all tool issues at TAC bases. Hence, the input measures of taxi services and tool issue were eliminated from the set of input measures.

From the remaining list of input measures, a final set of 16 input measures was developed. This list was developed by the HQ TAC/DEMG staff by combining some input measures and by eliminating those measures that were not considered relevant, or for which data was not readily available.

One area that was overlooked on the candidate set of measures was the number of overhires used in the Operations Branch. An overhire is a person hired on a part-time basis to augment the assigned number of personnel. This measure was included as one of the final input measures. See Table 4.2 for the list of input measures selected.

Data Collection

HQ TAC/DEMG distributed by message a request for data collection on the input and output measures of available resources from the 18 bases in the Tactical Air Command. (See Appendix C for message requesting data.) Data was collected for the months of March, April and May from each of the bases. The data for each month was first collected

TABLE 4.2

Input Measures Selected

Input:	Description:
1.	# of Bench Stock line items (GOCESS,COCESS, and Base Supply)
2.	# of Work Requests received
3.	# of Job Orders received
4.	# of material complete Work Orders
5.	# of material complete Job Orders
6.	# of General Purpose vehicles assigned to the Operations Branch
7.	Ratio of vehicles assigned to authorized
8.	1/average age of General Purpose vehicles
9.	# of skill levels filled (Military personnel in the Operations Branch)
10.	# of positions with correct grade filled (Military personnel in the Operations Branch)
11.	Total available manhours
12.	# of civilians assigned to the Operations Branch (exclude overhires)
13.	# of civilian overhires assigned to the Operations Branch
14.	Ratio of civilians assigned to authorized(all)
15.	# of Military personnel assigned to the Operations Branch
16.	Ratio of Military assigned to authorized

by HQ TAC/DEMG staff and then forwarded to AFIT where it was loaded into AFIT's Cyber computer system. Appendix D contains a complete listing of the data file. Each base did collect the required data elements for the desired months for a 100% return rate. Therefore, a total of 54 observations were loaded. Each base had three observations, designated for the months of March, April and May as "Base name" 1, 2, and 3 respectively.

The data file was formated to meet the requirements of the CFA programming code at the University of Texas, Austin, Texas. The CFA program is loaded on a Cyber computer system similar to the AFIT Cyber system. The first seven lines in the data file describes the format of the data to be read. Line 1 is the title of the data file and line 2 contains that number of observations to be read (54), the number of outputs (15), and the number of inputs (16) for each observation.

There is a total of 15 outputs in the data file because the final 8 output measures were added together to make 4 combined output measures. The output measures were combined to give some flexibility in the number of output measures used in the efficiency model. Output A is the sum total of direct manhours (summation of outputs 1 through 7). Output B is the total manhours used for work orders completed (output 1 and 2). Output C is the total manhours used for job orders completed (outputs 3, 4, and 5), and output D is the total manhours used for recurring work and utility operations (outputs 6 and 7). Outputs E, F, and G are empty data fields that were required to maintain the proper data format. By combining the outputs as described, the efficiency model can use two, four, or eight outputs and still contain all of the direct and indirect manhours.

Lines 3 through 7 in the data file describe the order in which the output and input measures will be read for each

observation. In this data file, outputs A through G will be read from the first line of data, followed by outputs 1 through 8 and then inputs 1 through 16. In the data record of each observation, the first line is the record identifier (the name of the base followed by the suffix corresponding to the appropriate month). Each record identifier is followed by five lines of data. The first 12 columns of each line contain the record identifier for the corresponding observation. Following the record identifier is the output and input measures in the order described in the formatting statement in lines 3 through 7.

V. Analysis and Results

Introduction

This chapter contains the analysis and results of the data in modeling the efficient use of available resources in the Operations Branch of a Base Civil Engineering Squadron. The analysis of the program executions was conducted at the University of Texas, Austin, from 25 to 28 June 1984. Dr. Authella Bessent and Dr. Wailand Bessent, Co-Directors of the Educational Productivity Council (supports the research and maintenance of the CFA code), were available to assist in the execution of the CFA program. The results of the program executions will be used to answer the research questions. Each research question is analyzed separately.

CFA Program Execution

The CFA execution commands were designed to add flexibility in the analysis of the data within an efficiency model. Once the data file is correctly loaded, the CFA code initializes the program execution by asking the user a set of five questions.

The first question asks the user to specify the decision making units (DMUs) to be included in the reference set. The units the user specifies will be the only units from the data file that will be used in the efficiency model. The user has the option of specifing a given set of DMUs or he can use all of the DMUs in the reference set.

All of the DMUs were included in the reference set in the program execution for modeling the efficient use of available resources.

The second question asks the user to specify the DMUs to be processed. The user has the option of processing a given set of DMUs or all of the DMUs from the reference set. Efficiency ratings and output reports are generated only for the units specified to be processed. This allows the user to run reports for only the inefficient units, and does not have to waste execution time on the efficient units from the reference set. If a unit is not specified in the reference set, it cannot be processed. The initial program executions for modeling the efficient use of available resources specified all of the DMUs to be processed. Once the ineffecient units were determined, a second program execution was conducted to generate the reports for the inefficient units.

The CFA program then requests the user to choose the outputs and inputs to be used in the efficiency model. These two questions allow the user to choose a subset of the output and input measures in the determination of efficiency for the DMUs in the reference set. The user has the option of specifying a subset or all of the output and input measures in the efficiency model. Various combinations of output and input measures were used in the modeling of efficient use of available resources.

The final question of the executive commands asks the user to specify which reports are to be executed. There are two reports generated for each unit specified to be processed. The first report is the output change report. This report identifies changes required in the output levels of a DMU in order to become efficient if the input levels remained constant. The second report, the input change report, identifies the changes required in the input levels of a DMU in order to become efficient if the output levels remained constant. The user has the option of specifying the output change reports, input change reports, both, or no reports. For this research effort, both reports were requested when the change reports were desired for a given program execution.

The output and input change reports were generated by printing the output file once the program had executed. The output file listed all command statements and responses, and the change reports for the units specified to be processed. The CFA model also generates a summary file and a lambda file that the user has the option of executing.

The summary file is a summary of the efficiency ratings, multiplier and surplus values for each unit specified to be processed. Appendix E contains a summary file for a program execution which specified processing all of the DMUs in the reference set with a subset of output and input measures. The second line in the summary file

identifies the number of units in the data file (54), the number of outputs used (4), and the number of inputs used (7). Lines 3 and 4 identify which outputs and inputs were selected for the program execution.

Following the execution statements, a summary record is generated for each DMU. For this program execution, each DMU has a summary record of seven lines. The lower and upper bound efficiency rating is found at the end of the line 0. Lines 1 and 4 contain the observed values for the output and input measures in the order specified in the execution statements. Lines 2 and 5 contain the multiplier values, μ_{rk} and ν_{ik}, for the output and input measures associated with DMU . The surplus values, S_{rk}, S_{ik} associated with the output and inputs of DMU are found on lines 3 and 6. These multiplier and surplus values are generated by the CFA model and are used to generate the output and input change reports in the output file. (See Appendix A for explanation of CFA terms.)

The lambda file specifies the inefficient units within the reference set and identifies those units that lie on the efficiency frontier closest to the inefficient unit. Appendix F is the lambda file associated with the summary file in Appendix E. The lambda file identifies all the inefficient units determined in the program execution using outputs B, C, D, 8 and inputs 1, 3, 6, 9, 11, 13, and 15. For example, England1 was determined to be inefficient.

The efficient units on the efficiency frontier closest to England1 are, therefore, Sey John2, Holloman1, Moody1, Nellis1, Luke3, Langley1, Davis Mon1, and Davis Mon3. The value to the right of the efficient units is the value of the vector from England 1 to the efficient units.

CFA Code Limitations

The initial program executions attempting to use all 8 output and 16 input measures for modeling the efficient use of available resources were unsuccessful. It was discovered that the CFA program code had been written using a matrix dimension of 20. The matrix is used to perform the linear programming calculations. The CFA program would not accept the initial program executions because they contained 24 constraints, one associated with each output and input measure, and would not fit in the matrix dimensioned for only 20 outputs and inputs.

The dimensioning problem was unique for the CFA efficiency model. For the first time a large set of output and input measures were being used. The CFA model had only been used to model efficiencies in organizations with 3 output measures and 10 input measures. The CFA program itself could handle more than 20 output and input measures, but the computer program had been dimensioned for a maximum of 20 output and input measures. Doctors A. Bessent and W. Bessent did make several attempts to redimension the CFA program code, but their efforts were unsuccessful. The CFA

program code was too complicated and would require an in-depth analysis in order to correctly redimension the code to handle more than 20 output and input measures.

Reduction of Output and Input Measures

The unforseen problem of the CFA code dimension limitations made it necessary to reevaluate the output and input measures and reduce the number of measures so that the CFA program could execute the data. The CFA program had the flexibility of specifying a subset of outputs and inputs built into the executive commands. By choosing a subset of less than 20 output and input measures, the CFA program would execute on the data file and produce the required efficiency ratings for the DMUs in the data file.

Since the 8 output measures had been combined, there was some added flexibility in the number of output measures that could be specified. By using output A, direct manhours, and output 8, indirect manhours, only two outputs could be used to describe all of the output processes for a Civil Engineering Operations Branch. The problem with using two output measures is that it limited the variation in output between the organizations. The aggregation of output measures compacted the variation in resources used to accomplish the output processes.

A better combination of aggregated output measures was output B, manhours used in completion of Work Orders; output

C, manhours used in completion of Job Orders; output D, manhours used in Recurring Work and Utility Operations; and output 8, Indirect Manhours. This combination of outputs aggregated the output processes, yet still allowed for variation between organizations. Of all the combinations of output measures tested, the use of these four outputs produced the best results in the model.

Unlike the output measures, the input measures for the efficiency model could not be aggregated because each input was not measured with the same unit of measure. All of the outputs were measured in manhours and, therefore, could be combined. The input measures included a variety of measures. As stated earlier, a subset of input measures could be specified by the user in order to reduce the number of inputs.

The CFA model recommended that there be at least two observations for every one output/input measure used in the efficiency model. By using only four output measures, all 16 input measures could be used in the efficiency model. Using 20 output and input measures with 54 observations did meet the model requirements, but it was discovered that a ratio of observations to output/input measures that is close to 2.0 did not produce very many inefficient units. When 4 output measures and 14 input measures were used in the program execution, only 5 out of the 54 units were rated as inefficient.

Tests using reduced numbers of output and input measures produced results that identified more inefficient units. When there is a low ratio of observations to output/input measures, there are so many combinations of output and input measures that every unit can look efficient on some part of the efficiency frontier. By reducing the number of output and input measures, the number of combinations is reduced, thus limiting the number of units that can reach the efficiency frontier.

Pearson Correlation Results

In order to justify the elimination of input measures, the subprogram for a Pearson Correlation from the Statistical Package for the Social Sciences (SPSS) was calculated for the input measures paired with the output measures. The results of the Pearson Correlation produced several interesting relationships between the input measures and output measures. From these results the input measures were systematically eliminated from the efficiency model.

The Pearson Correlation measures the strength of the relationship between two variables. A high positive value corresponds to a strong relationship between variables. A value close to zero means there is little relationship between the two variables. A negative correlation between variables indicates an opposite relationship between variables. For the efficiency model variables, a positive correlation would indicate that an increase in the input

variable corresponds to a positive effect on output, a zero correlation would indicate no relationship between input and output, and a negative correlation would mean that an increase in the input variable would lead to a decrease in the output variable.

Upon completion of the Pearson Correlation on the data file, it was found that there was a negative correlation between several of the input measures and the output measures. Input measures 14 and 16 had a negative correlation with the majority of the output measures. Referring back to the list of input measures, input 14 is the ratio of civilians assigned to the number of authorized, and input 16 is the ratio of military assigned to the number authorized. The Pearson Correlation suggested that as the ratio of personnel assigned to the number authorized increases, the output for a unit decreases. Logically this result makes sense because as a unit gets closer to filling all of its authorized positions, or possibly has more assigned than authorized, the productivity of each individual will decrease since they will not have to do as much work as when the organization was undermanned. Due to this negative relationship between input and output, inputs 14 and 16 were not used in the efficiency model.

Another input measure that produced a negative correlation with the majority of the output measures was input 4, the number of material complete Work Orders in the

Material Control holding area. Input 4 had a positive correlation for the outputs that measured the number of manhours used for completing Work Orders, outputs 1, 2, and B, but there was a high negative correlation between input 4 and the rest of the output measures. Again, this result logically makes sense because the number of material complete Work Orders will only increase output used for completing Work Orders, and will detract from the output used for the other output processes. Hence, input 4 could still be considered as an alternative input measure for the efficiency model.

The Pearson Correlation also revealed some other interesting relationships between input variables. A high positive correlation existed between several of the input variables. Input 9 and input 10 had a correlation of .9384 which indicates a very high positive relationship between the two variables. Input 9 measured the number of military positions with the correct skill level filled, and input 10 measured the number of military positions with the correct grade filled. There was also a high positive correlation (.8531) between input 9 and input 15, the number of military assigned, and between input 10 and 15 (.8235). Input 11, the total available manhours, and input 12, the number of civilians assigned, also had a strong positive correlation (.6298).

As stated earlier, a high positive correlation indicates a strong relationship between variables. In the efficiency model, a high positive correlation indicates that the two variables are closely related and, therefore, only one of the variables need to be used an an input measure. In this case, input 9 could be used as an input measure and inputs 10 and 15 could be eliminated from the list of input measures. Also, input 11 could be used and input 12 could be eliminated. This reduces three of the input measures in the efficiency model by discarding the input measures that are already represented in other input measures.

Research Question 1

"Which variables describe a unit's available resources?"

From the candidate list of output and input variables, 24 variables were selected as the output and input measures for modeling the efficient use of available resources. Due to the limitations of the CFA program code, all of the output and input measures could not be used. Further reductions in the list of measures had to be made before the program could be executed on the data file.

The output measures were reduced by combining the 8 original output measures into 4 output measures. Table 5.1 shows the final set of output measures used in the efficiency model for available resources. By aggregating the output processes into these four outputs, the description of the Operations Branch was maintained.

TABLE 5.1

Reduced Output Measures

Output	Description	Data File Identifier
1	Manhours used in completing Minor Construction and Other Work Orders	Output B
2	Manhours used in completing Emergency, Urgent, and Routine Job Orders	Output C
3	Manhours used for Recurring Work and Utility Operations	Output D
4	Indirect manhours	Output 8

The input measures could not be reduced by combining various inputs. The input measures were reduced by comparing input variables using the Pearson Correlation results. Several input measures were eliminated because there was a negative relationship between the input measure and outputs. Other input measures were discarded because there was a high positive correlation between input measures. The final set of input measures used in the efficiency model contained seven input measures. The seven inputs measures in Table 5.2 were the input measures selected based on the Pearson Correlation results. The seven measures showed the highest correlation with the output measures.

TABLE 5.2

Reduced Input Measures

Input	Description	Data File Identifier
1	Number of Bench Stock Line Items (COCESS, GOCESS, and Base Supply)	Input 1
2	Number of Job Orders received	Input 3
3	Number of Vehicles assigned	Input 6
4	Number of military positions at least the correct skill level filled	Input 9
5	Total available manhours	Input 11
6	Number of civilian overhires	Input 13
7	Number of military assigned	Input 15

Research Question 2

"How will the variables be weighted?"

As stated in previous discussions, it is not necessary to assign weights to the output and input variables. The weight assigned to an output or input variable is determined by the CFA model. The weighting assigned to each variable is unique for each organization based on how that organization is using its available resources in comparison with the other organizations in the reference set.

Appendix E contains a summary file for the CFA model executed on the data for available resources using the

output and input measures identified in Research Question 1. The multiplier values for each output/input measure are found on lines 2 and 5 in the data record for each DMU. These values are determined in the linear progamming calculations of the CFA model. The multiplier values are used to determine the relative importance of the output/input measure found in Change Reports for the given DMU.

Table 5.3 is an Output Change Report for DMU 1. The "percent contribution to efficiency" represents the weighting assigned to each output variable for DMU 1. The percent contribution is calculated by multiplying the observed value of the output measure by the multiplier value for that output measure. For example, output C contributes 42.3 percent to the efficiency of DMU 1. From the summary file in Appendix E, the multiplier value, for output C for Bergstrom 1 is .000032 and the observed value for output C is 13287.0. Multiplying the observed value by the multiplier value equals the percent contribution to efficiency.

$$\text{Percent Contribution to efficiency} = \text{multiplier value}, \mu_{rk} \times \text{observed value} \times 100\%$$

$$42.3\% = (.000032) \times (13287.0) \times 100\%$$

There will be slight difference in the calculated values due to rounding errors.

The same principle holds true for the input measures. The "relative importance of inputs", which represents the weighting of the input measure, is determined by multiplying the observed value by the multiplier value, ν_{ik}. For input 6 in the DMU 1 Output Change Report in Table 5.3, the relative importance equals 27.0%.

$$\text{Relative Importance of Inputs} = \text{multiplier value } \nu_{ik} \times \text{observed value} \times 100\%$$

$$27.0\% = (.006933) \times 39.0 \times 100\%$$

<u>Research Question 3</u>

"*Which* variables significantly impact the efficient use of available resources?"

As pointed out in Research Question 2, the CFA efficiency model assigns weights to each output and input variable for a given DMU based on a simultaneous comparison of all DMUs. The weights are determined by using the multiplier values, μ_{rk} and ν_{ik}, generated by the CFA model. The weights assigned to each output/input variable is unique for the DMU being evaluated. The relative importance assigned to a variable will vary between DMUs. The CFA model is unique in the fact that it determines the importance of a variable based on observed values for DMUs being evaluated.

TABLE 5.3

Output Change Report for DMU 1

MODEL EFF OF AVAIL RES
DECISION MAKING UNIT 1

****
* SUMMARY OF RESULTS *
****

EFFICIENCY RANGE = 87.4 TO 97.7 PERCENT
MULTIPLIER FOR EFFICIENT OUTPUT LEVELS = 1.144

****
* OUTPUTS *
****

	OBSERVED VALUES	EFFICIENT OUTPUT LEVELS	PERCENT CONTRIBUTION TO EFFICIENCY
OUTPUT B	5527.0	6323.3	16.9
OUTPUT C	13287.0	15201.4	42.3
OUTPUT D	6746.0	7718.0	5.2
OUTPUT 8	8810.8	10080.3	23.0
		TOTAL :	87.4 PERCENT

****
* Inputs *
****

	OBSERVED VALUES	NO INPUT CHANGES REQUIRED	RELATIVE IMPORTANCE OF INPUTS
INPUT 1	2736.0		11.9
INPUT 3	1249.0		.2
INPUT 6	39.0		27.0
INPUT 9	98.0		17.9
INPUT 11	29562.0		43.0
INPUT 13	32.0		.0
INPUT 15	129.0		.0
		TOTAL:	100.0 PERCENT

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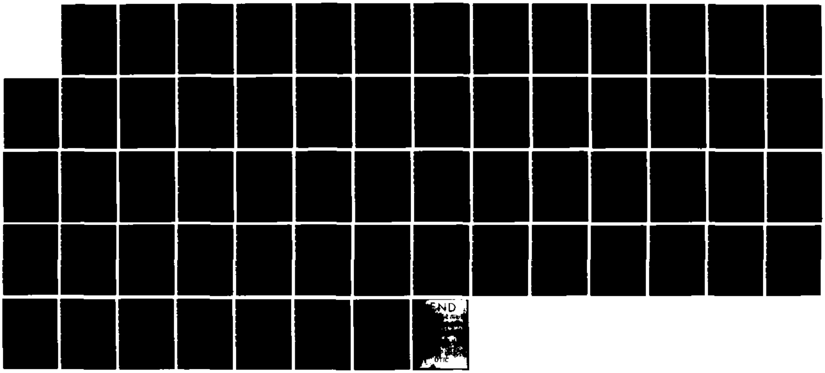
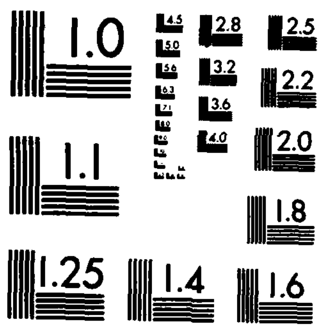
UNCLASSIFIED SEP 84 AFIT/GEM/LSM/84S-8 F/G 5/1 NL




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

In the case of multiple output, multiple input analysis, there are many combinations of outputs and inputs that an organization can achieve. One organization may put more effort into output 1, while another may emphasize output 3. Therefore, the significance of a variable can only be determined for the organization being evaluated. The CFA model identifies the percent contribution to efficiency for the output variables, and relative importance of input variables. The output and input variables with the highest percentages are the most significant variables for the DMU being evaluated.

Table 5.5 shows the Output Change Report for DMU 51. The efficiency range for DMU 51 is similar to the efficiency range for DMU 1, yet when comparing the percent contribution to efficiency for the output variables (See Table 5.4) there is a significant difference in the percentages between the two units.

TABLE 5.4

Comparison of Variable Significance

	Percent Contribution to Efficiency	
Output	DMU 1	DMU 51
B	16.9	44.8
C	42.3	.0
D	5.2	41.8
8	23.0	1.1

TABLE 5.5

Output Change Report for DMU 51

MODEL EFF OF AVAIL RES
DECISION MAKING UNIT 51

```
**********************
* SUMMARY OF RESULTS *
**********************
```

EFFICIENCY RANGE = 87.7 TO 94.8 PERCENT
MULTIPLIER FOR EFFICINET OUTPUT LEVELS = 1.141

```
***********
* OUTPUTS *
***********
```

	OBSERVED VALUES	EFFICIENT OUTPUT LEVELS	PERCENT CONTRIBUTION TO EFFICIENCY
OUTPUT B	4615.0	5264.2	44.8
OUTPUT C	9916.0	13711.6	.0
OUTPUT D	9593.0	10942.5	41.8
OUTPUT 8	5735.0	6541.8	1.1
		TOTAL:	87.7 PERCENT

```
**********
* INPUTS *
**********
```

	OBSERVED VALUES	NO INPUT CHANGES REQUIRED	RELATIVE IMPORTANCE OF INPUTS
INPUT 1	1868.0		23.4
INPUT 3	1316.0		.0
INPUT 6	38.0		36.4
INPUT 9	141.0		16.0
INPUT 11	29859.0		.4
INPUT 13	11.0		9.1
INPUT 15	185.0		14.6
		TOTAL:	100.0 PERCENT

Both units were able to achieve approximately the same efficiency rating, while putting their emphasis on different outputs. The significant output variables for DMU 1 would be outputs B, C, and 8, whereas the significant variables for DMU 51 would be outputs B and D.

Research Question 4

"Can tradeoffs and recommendations be found which allow inefficient organizations to improve their efficiency?"

The CFA efficiency model generates two reports, the Output Change Report and Input Change Report, for each DMU. The information from the reports can be used by managers to improve their efficiency in the use of their available resources. Each report must be evaluated separately in order for resource managers to determine the best course of action.

Table 5.6 shows a typical Output Change Report for the available resource efficiency model. In comparison with the other 53 units in the reference set, the CFA model determined that DMU 24 was an inefficient unit. The efficiency rating is found on the first line of the summary of results. The Output Change Report identifies the changes required in the output levels to make the unit efficient while keeping the inputs at the same levels. The efficient output levels are determined by multiplying the observed output values by the multiplier value for efficient output and subtracting any surplus, , that may be present.

TABLE 5.6

Output Change Report for DMU 24

```
MODEL EFF OF AVAIL RES
DECISION MAKING UNIT 24

                    ***********************
                    * SUMMARY OF RESULTS *
                    ***********************

EFFICIENCY RANGE =  88.3  TO  95.2  PERCENT
MULTIPLIER FOR EFFICIENT OUTPUT LEVELS =  1.132

                         ***********
                         * OUTPUTS *
                         ***********

              OBSERVED     EFFICIENT       PERCENT
               VALUES      OUPUT         CONTRIBUTION
                           LEVELS        TO EFFICIENCY

OUTPUT B       2018.0       2284.2          15.6
OUTPUT C      16680.4      18880.5          29.2
OUTPUT D       7635.2       8642.3          19.8
OUTPUT 8      10629.5      12031.5          23.7
                                         --------------
                                TOTAL:      88.3 PERCENT
                                         --------------

                          **********
                          * INPUTS *
                          **********

              OBSERVED     NO INPUT      RELATIVE
               VALUES      CHANGES       IMPORTANCE
                           REQUIRED      OF INPUTS

INPUT 1        1389.0                        8.9
INPUT 3        2494.0                         .0
INPUT 6          28.0                       22.8
INPUT 9          97.0                        6.0
INPUT 11      40167.5                       42.6
INPUT 13          5.0                         .8
INPUT 15         98.0                       18.8
                                         --------------
                                TOTAL:     100.0 PERCENT
                                         --------------
```

The surplus values are found on lines 3 and 6 of each data record in the summary file (See Appendix E). A manager would want to improve output levels to the efficient output levels in the Output Change Report in order to become efficient.

The calculations of the percent contribution to efficiency for the output variables and the relative importance of inputs was discussed for Research Questions 2 and 3. The higher the percentage, the more significance the model is putting on an output or input variable. Therefore, a manager would want to put efforts into improving those variables with the lowest percentage or importance since those are the variables that are contributing the least to the efficiency of the unit.

The Input Change Report determines the input levels required for a DMU to become efficient while maintaining the output levels at their current values. Like the output change levels, the efficient input levels are calculated by multiplying the observed input values by the multiplier for efficient input levels and subtracting any surplus, . A manager would again emphasize those inputs with the lowest relative importance since they are detracting from the efficiency of the DMU. Table 5.7 is an example of an Input Change Report. A manager would first put efforts on improving input 3 in order to improve the efficiency of his unit.

TABLE 5.7

Input Change Report for DMU 24

MODEL EFF OF AVAIL RES
DECISION MAKING UNIT 24

```
**********************
* SUMMARY OF RESULTS *
**********************
```

EFFICIENCY RANGE = 88.3 TO 95.2 PERCENT
MULTIPLIER FOR EFFICIENT INPUT LEVELS = .883

```
***********
* OUTPUTS *
***********
```

	OBSERVED VALUES	NO OUTPUT CHANGES REQUIRED	PERCENT CONTRIBUTION TO EFFICIENCY
OUTPUT B	2018.0		15.6
OUTPUT C	16680.4		29.2
OUTPUT D	7635.2		19.8
OUTPUT 8	10629.5		23.7
		TOTAL:	88.3 PERCENT

```
**********
* INPUTS *
**********
```

	OBSERVED VALUES	EFFICIENT INPUT LEVELS	RELATIVE IMPORTANCE OF INPUTS
INPUT 1	1389.0	1227.1	8.9
INPUT 3	2494.0	2067.8	.0
INPUT 6	28.0	24.7	22.8
INPUT 9	97.0	85.7	6.0
INPUT 11	40167.5	35486.8	42.6
INPUT 13	5.0	4.4	.8
INPUT 15	98.0	86.6	18.8
		TOTAL:	100.0 PERCENT

Following the Output Change Report and Input Change Report, the CFA model provides a list of efficient units that make up the efficiency frontier closest to the inefficient unit. Table 5.8 shows the list of the efficiency frontier units for DMU 24, Howard 3. The units identified in this set have a similar mix of outputs and inputs as the inefficient unit. A manager would study these efficient units and attempt to model his unit after the efficient units.

TABLE 5.8

Efficiency Frontier for DMU 24

MODEL EFF OF AVAIL RES

DECISION MAKING UNIT 24 HOWARD3

****
****

X	NELLIS1	.19615
X	HOWARD1	.64446
X	MOODY1	.34292
X	GEORGE3	-.25442
X	BERGSTROM3	-.25695
X	SEY JOHN2	-.01498
X	LUKE3	.10689
X	MACDILL3	.04753
X	MOODY2	.11858

The CFA efficiency model also provides Output and Input Change Reports for the efficient units. Table 5.9 is an example of an Input Change Report for an efficient unit. If a unit has been identified as an efficient unit, there are no required changes in the output or input levels. Even though there are no required changes in the output and input levels, there is information to be gained from these reports for the efficient units.

In the case of DMU 4 in Table 5.9, it was identified as an efficient unit, yet 100 percent of the contribution to efficiency came from output 8, indirect manhours. A manager may evaluate this result and determine that even though his unit was determined to be efficient, too much emphasis was being placed on one output.

The same principle holds true for the relative importance of the input values. A manager would want to investigate those inputs that have little or no relative importance to determine if the inefficiencies are being covered up by the more significant values.

The reports generated by the CFA efficiency model provide a lot of information that can be used by managers to more efficiently operate their unit. The information allows the manager to make tradeoffs between inputs and outputs, and provides many alternative courses of action. Information is not only available for the inefficient units, but also for efficient units. A manager must evaluate the

TABLE 5.9

Input Change Report for an Efficient Unit

MODEL EFF OF AVAIL RES
DECISION MAKING UNIT 4

****
* SUMMARY OF RESULTS *
****

EFFICIENCY RANGE = 100.0 TO 100.0 PERCENT
MULTIPLIER FOR EFFICIENT INPUT LEVELS = 1.000

****
* OUTPUTS *
****

	OBSERVED VALUES	NO OUTPUT CHANGES REQUIRED	PERCENT CONTRIBUTION TO EFFICIENCY
OUTPUT B	332.5		.0
OUTPUT C	5808.5		.0
OUTPUT D	3845.8		.0
OUTPUT 8	10649.9		100.0
		TOTAL:	100.0 PERCENT

****
* INPUTS *
****

	OBSERVED VALUES	EFFICIENT INPUT LEVELS	RELATIVE IMPORTANCE OF INPUTS
INPUT 1	2526.0	2526.0	.0
INPUT 3	1561.0	1561.0	.0
INPUT 6	9.0	9.0	90.2
INPUT 9	139.0	139.0	.0
INPUT 11	23992.0	23992.0	1.4
INPUT 13	7.0	7.0	7.0
INPUT 15	137.0	137.0	1.4
		TOTAL:	100.0

results for his unit and then base appropiate actions on the unique characteristics of his unit.

The number of outputs and inputs selected also affects the number of units identified as efficient or inefficient. Table 5.10 shows a comparison of the number of output and inputs selected. As fewer variables are used in the efficiency model, the size of the efficiency frontier becomes smaller, thus reducing the number of units that can reach the efficiency frontier.

TABLE 5.10

Comparison of Outputs and Inputs Selected

Number of Outputs	Number of Inputs	Total	Ratio of Observations to Outputs and Inputs	Number of Inefficient Units	Percent Efficient
2	16	18	3.00	5	90.7
4	14	17	3.18	6	88.8
4	9	15	3.60	8	85.2
2	11	13	4.15	17	68.5
4	8	12	4.50	13	75.9
4	7	11	4.91	14	74.1
2	8	10	5.40	30	44.4
4	5	9	6.00	21	61.1

VI. Conclusions and Recommendations

Introduction

This chapter presents the conclusions based on the results from the model developed to measure the efficient use of available resources in the Operations Branch of a base level civil engineering organization. The limitations of the CFA efficiency model were discussed in the previous chapters. The effects of the model limitations will be presented in the chapter along with recommendations to improve the efficiency model for available resources.

Specific Conclusions

McKnight and Parker (1983) initiated a research effort to develop an organizational effectiveness model for base level civil engineering organizations. Their research effort generated a nine-factor effectiveness model based on inputs from wing, base, and civil engineering commanders. They concluded with recommendations to further develop the model by

1. Standardize definitions for each of the nine factors.

2. Develop measurement criteria.

3. Test and validate the model for use by base civil engineers at CONUS Air Force installations.

The objective of this research effort was to accomplish these three tasks for Factor 4, Resource Availability, of

the organizational effectiveness model. The use of available resources was perfectly suited for developing an efficiency model. The use of resources provides a quantitative measure that can be evaluated in a mathematical model. The specific conclusions from this research effort are discussed below:

1. A standardized set of measurement criteria was developed for modeling the efficient use of available resources. The list of measures was based on current base level civil engineering procedures. From a list of 46 candidate measures, a set of output and input measures were developed to measure efficient use of available resources in the Operations Branch. Table 4.1, page 61, and Table 4.2, page 65, list the output and input measures selected to describe the use of available resources.

2. Data was collected from the 18 Tactical Air Command bases for a three month time frame. Each base submitted the data for the required output and input measures. Each base had three months of data representing three observations for the efficiency model.

3. The 54 data observations were used in the Constrained Facet Analysis model at the University of Texas, Austin to determine if the effcient use of available resources could be modeled. Due to CFA program code limitations, the complete set of 8 output and 16 input measures could not be used. The set of measures was reduced by aggregating the

output measures into 4 outputs and reducing the input measures to a set of 7 inputs. The input measures in the final selection were based on results from a Pearson Correlation executed on the data file of outputs and inputs. The final set of measures was then executed in the CFA program. The CFA model did provide efficiency ratings for the data observations. Appendix E provides a summary of the efficiency ratings, multiplier values, and surplus values for the 54 observations in the data set. Tables 5.3 - 5.9 are examples of the Output Change Reports and Input Change Reports generated for the inefficient and efficient units. The reports generated by the model provided information on the significance of output and input variables, and identified areas where improvements could be made which would allow inefficient units to achieve an efficient rating. The model also provided the inefficient unit with a list of efficient units that made up the efficiency frontier closest tho the inefficient unit. The units identified had similar mixes of outputs and inputs as the inefficient units.

Effects of CFA Program Limitations

As stated in Chapter 5, an unforseen problem arose with the CFA programming code. The CFA model was ony able to execute on data with less than 20 output and input variables. Due to these limitations, the set of 24 output

and input measures had to be reduced. Reducing the measures used in the efficiency model affected the description of the process being measured. Since all of the measures could not be included in the model, a complete description of the process was not being modeled. This lack of description of the process being modeled affected the information produced by the efficiency model. In order to correctly identify all the inefficiencies within an organization, the complete description of the process being modeled must be present in the efficency model.

The CFA model is also limited in the number of inefficient units identified when using a large set of output and input measures compared to a relatively small set of oservations. The model recommends a ratio of observations to number of outputs and inputs of 2 to 1. The CFA program code limited the number of output and inputs used in the model to less than 20, yet when only 18 output and input measures were used with the 54 observations, only 5 units were identified as inefficient. Table 5.10 shows the ratio of observations to output and input measures, and the number of inefficient units identified for different combinations of output and input measures. Further research in this area should take into account the limitations imposed when large sets of output and input measures are used with a small set of observations.

Recommendations

This research effort has shown that the CFA model can be used to model the efficient use of available resources in the Operations Branch of a base level civil engineering organization. The following specific recommendations are offered for further consideration.

1. Redimension the CFA computer program code to a dimension greater than 20. By accomplishing this task the entire set of output and input variables could be used in the efficiency model. The CFA model theory will work for a model with more than 20 output and input variables, but the current CFA computer program limits the number of variables that can be used.

2. Collect data from all CONUS Air Force installations. By collecting data from all CONUS bases, the number of observations in the data file can be increased. Comparisons can then be made between units in various commands or by isolating just one set of bases. The CFA executive commands allow flexibility in the selection of units to be evaluated in the reference set, and in the selection of units to be processed.

3. Collect data on all measures in the candidate list of output and input variables. A Pearson Correlation can then be executed on all measures to determine which variables are best suited for measuring available resources. Again, the CFA executive commands provide the flexibility

of selecting a subset of output and input measures.

4. Instead of using manhours completed in the various output processes, a more appropriate measure of output may be the original set of 10 output measures discussed in Chapter 3. As stated in Chapter 4, the output measures selected are actually process measures, not results measures. The manhour data should be used as input variables for the efficiency model. Data could be easily collected on the number and cost of work orders and job orders being completed at CONUS installations. The author believes that this data would provide a better description of the output for a unit and would better identify those units that are efficient. It would identify those units that have higher personnel productivity levels.

A study could also be conducted which compares the variation of manhours/work order between the observations in the data file. If the standard deviation of manhours/work order is small, then assumptions could be made that the number of work orders accomplished per month is not greatly affected by the size of the work orders for a particular base. The same approach could be used when comparing the variation of manhours/job order between observations. If little variation exists between observations, then data on the number of work orders and job orders being completed can be used to measure the output for a civil engineering unit.

5. The CFA efficiency model can be used to measure the efficiency of other areas of a civil engineering unit. Current research efforts are being conducted to determine the efficiency of base level civing engineering Fire Departments (Byers and Waylett, 1984), and Engineering Design (Astin and Ruff, 1984). Further research efforts should concentrate on modeling the efficiency of other areas of civil engineering organizations. Once all research is completed, the CFA model could be used Air Force wide to model the efficiency of civil engineering organizations. The CFA model could also be used to compare subunits within civil engineering. For example, a model could be developed to compare the different shops in the Operations Branch of a civil engineering unit.

6. Once the model is operational for all applicable inputs and outputs, implement the CFA efficiency model as a management tool to be used by Air Force civil engineering managers to improve the efficiency, and thus, the productivity and effectiveness of base level civil engineering organizations.

Appendix A: Model Used in Constrained Facet Analysis of Not Fully Enveloped Units

The model used in the iterative method called constrained facet analysis is presented in this appendix, a model which can be used in evaluating the range of inefficiency in organizational units and in determining marginal rates of substitution and productivity in frontier facets.

Suppose one wishes to evaluate the relative efficiency of n decision making units (DMUs), each of which uses varying amounts of m inputs and produces varying amounts of s outputs. Using notation conventions similar to those used by Clark (1982) let:

x_{ij} = the amount of input type i used by DMU j during the period of observation, $i = 1, 2,\ldots,m$ and $j = 1, 2,\ldots,n$.

y_{rj} = the amount of output type r produced by DMU j during the period of observation, $r = 1, 2,\ldots,s$ and $j = 1, 2,\ldots,n$.

x_{ik} = the amount of input type i used by the unit k where $k \quad j = 1, 2,\ldots,k,\ldots,n$ and unit k is the DMU being evaluated. Each DMU in turn will be evaluated.

y_{rk} = the amount of output type r used by DMU_k.

N = $1, 2, 3,\ldots,M$ is the sequence of iterations of the constrained facet analysis model which ends at iteration M.

$h_k^{(1)}$ = the upper bound efficiency value sought for DMU_k which is determined from the solution of the first iteration of the constrained facet analysis.[1]

$h_k^{(M)}$ = the lower bound efficiency value sought for DMU_k which is determined from the solution of the final iteration (M) of the constrained facet analysis.

$\nu_{ik}^{(N)}$ = the multipliers for each input type i which will be determined by solution of the Nth iterative model.

$\mu_{rk}^{(N)}$ = the multipliers for each output type r which will be determined by solution of the Nth iterative model.

$s_{rk}^{(N-1)*}$ = the dual surplus values associated with outputs $r = 1, 2, \ldots, s$ of DMU_k at optimality of the previous iteration. For the initial iteration, these surplus values are $s_{rk}^{(N-1)*} = s_{rk}^{(0)*} = y_{rk}$.

$s_{ik}^{(N-1)*}$ = the dual surplus values associated with inputs $i = 1, 2, \ldots, m$ at optimality of the previous iteration. Initial values at iteration one are $s_{ik}^{(N-1)*} = s_{ik}^{(0)*} = x_{ik}$.

[1] The form of the constrained facet analysis model used in the first iteration is similar to the Data Envelopment Analysis (DEA) model of Charnes, Cooper and Rhodes (19 however the non-Archimedean infinitesimal quantities are not required.

The following linear programming model is used in constrained facet analysis for each iteration $N = 1, 2, \ldots M$:

<u>Primal</u>

$$\text{Max} \quad f_k^{(N)} = \sum_{r=1}^{s} \mu_{rk}^{(N)} s_{rk}^{(N-1)*} + \sum_{i=1}^{m} \nu_{ik}^{(N)} s_{ik}^{(N-1)*} \tag{1}$$

$$\text{s.t.} \quad \sum_{r=1}^{s} \mu_{rk}^{(N)} y_{rj} - \sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ij} = 0 \quad \text{for } j \in E_k^{(N)}$$

$$\sum_{r=1}^{s} \mu_{rk}^{(N)} y_{rj} - \sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ij} \leq 0 \quad \text{for } j \in \bar{E}_k^{(N)}$$

$$\sum_{i=1}^{m} \nu_{ik}^{(N)} x_{ik} = 1$$

$$\mu_{rk}^{(N)}, \ \nu_{ik}^{(N)} > 0$$

where

$E_k^{(N)} \equiv \{j/j\text{th constraint holds with equality at optimality at iteration } N-1\}$

$\bar{E}_k^{(N)} \equiv \{j/j\text{th constraint is} < 0 \text{ at optimality of iteration } N-1\}$

$E_k^{(1)} \equiv \Phi$ (empty), $\bar{E}_k^{(1)} \equiv \{1, 2, \ldots, n\}$.

The upper and lower bound efficiency measures are obtained from solution of the first and last iterative models as shown below:

$$h_k^{(1)} = f_k^{(1)} - 1 = \sum_{r=1}^{s} \mu_{rk}^{(1)*} y_{rk}$$

$$h_k^{(M)} = \sum_{r=1}^{s} \mu_{rk}^{(M)*} y_{rk}$$

The dual of model (1) above is:

<u>Dual</u>

$$\text{Min } \omega_k^{(N)} \tag{2}$$

s.t.
$$\sum_{j\epsilon E^{(N)}} \lambda_j^{(N)} y_{rj} + \sum_{j\epsilon \bar{\bar{E}}^{(N)}} \gamma_j^{(N)} y_{rj} - s_{rk}^{(N)}$$

$$= s_{rk}^{(N-1)*} \qquad r = 1,2,\ldots,s$$

$$x_{ik}\omega_k^{(N)} - \sum_{j\epsilon E^{(N)}} \lambda_j^{(N)} x_{ij} - \sum_{j\epsilon \bar{\bar{E}}^{(N)}} \gamma_j^{(N)} x_{ij} - s_{ik}^{(N)}$$

$$= s_{ik}^{(N-1)*} \qquad i = 1,2,\ldots,m$$

$$\omega_k^{(N)},\ \lambda_j^{(N)} \text{ unrestricted; } \gamma_j^{(N)},\ s_{rk}^{(N)},\ s_{ik}^{(N)} \geq 0$$

The mathematical theory and proofs related to the development of this model can be found in Clark (1982). They will not be repeated in this paper, but there are a few model characteristics which are worth noting here.

First, the efficiency measures $hk^{(1)}$ and $h_k^{(M)}$ are scalar <u>ratio</u> measures. Secondly, the constraints of the primal problem insure that the maximum achievable value of these efficiency measures is 1. Furthermore, constrained facet analysis does not require that outputs or inputs have common scales or units of measurement, an important attribute when dealing with difficulties such as nonmonetary objectives and nonpurchased resources, however; all measured input and output values are required to be strictly positive. Finally, each unit is compared to others in the set which have similar input/output mixes, i.e., those units in its "neighborhood".

In short, the constrained facet analysis model can identify units which are efficient or inefficient relative to a neighborhood frontier region of actual achievement; it can provide a limited number of clues on possible causes from analysis of surplus variables and multipliers; and it is helpful in evaluating the impact of alternative mixes of inputs and outputs.

Furthermore, the information provided by the constrained facet analysis model is a major improvement over the inadequate, partial (and sometimes inaccurate) measures

of performance which are now typically in use in many public service organizations. In addition to its usefulness as a performance monitoring device, this efficiency analysis tool opens the door for further development and growth in other areas of planning, resource allocation and decision support.

Reprinted from: "Constrained Facet Analysis, A New Method for Evaluating Local Frontiers of Efficiency and Performance" (Bessent, Bessent, Clark, and Elam; 1983)

Appendix B: Bases Used in Research

Tactical Air Command Bases

1. Bergstrom
2. Cannon
3. Davis Monthan
4. England
5. George
6. Holloman
7. Homestead
8. Howard
9. Langley
10. Luke
11. MacDill
12. Moody
13. Mountain Home
14. Myrtle Beach
15. Nellis
16. Seymour Johnson
17. Shaw
18. Tyndall

Appendix C: Data Collection Request

UNCLASSIFIED !(303) FILE: 5A-1!

~~120000Z~~ 13/915 Mel

01 06 13/915 APR 84 RR RR UUUU DEMG/3212

HQ TAC LANGLEY AFB VA//DEMG//

AIG 7342//DE//

ZEN 1CSG LANGLEY AFB VA//DE//

554OSW NELLIS AFB NV//DE//

XMT 554CSG NELLIS AFB NV

4450TG NELLIS AFB NV

834CSG HURLBURT FLD FL

ACCT AF-ACXJRF

UNCLAS

SUBJ: DATA COLLECTION ON RESOURCE AVAILABILITY.

SUSPENSES: SEE PARA 4B.

1. IN OUR CONTINUING EFFORT TO FIND BETTER WAYS TO UTILIZE OUR RESOURCES, WE ARE ALWAYS INTERESTED AND SUPPORTIVE OF AFIT OR OTHER GRADUATE STUDENTS DOING RESEARCH ON CIVIL ENGINEERING PRODUCTIVITY AND EFFICIENCY. AS SUCH, WE ARE NOW WORKING WITH AN AFIT STUDENT, LT FISHER, ON A MODEL WHICH SIMULTANEOUSLY ANALYZES THE IMPACTS ON EFFICIENCY UNDER MULTIPLE INPUT AND OUTPUT REQUIREMENTS. IN SUPPORT OF THIS EFFORT, WE WILL NEED TO COLLECT SOME BASE LEVEL DATA FOR THE PERIOD MAR, APR, AND MAY 84. WE HAD DIFFICULTY ON A PREVIOUS DATA COLLECTION EFFORT BECAUSE OF THE LEVEL OF EFFORT NECESSARY TO GATHER

For

MAJ KOC[illegible]NEK/ENGR MGT SYS OFF
TAC DEM[illegible]3212/AB

SIGNED

WAYNE T. F[illegible]ER, Lt Col DEMAB 846
Dep Dir [illegible] [illegible]ions & Maintenance

!DEMG/ ! 12 Apr

UNCLASSIFIED ~~120000Z~~ 13/915 APR 84

THE INFORMATION. WE'VE TRIED TO PROFIT FROM OUR PREVIOUS MISTAKES AND HAVE WORKED CLOSELY WITH LT FISHER ON THE DATA ELEMENTS SELECTED.

2. DATA TO BE COLLECTED IS AS FOLLOWS:

A. OUTPUT MEASURES: TYPE DATA - SOURCE.

[1] MONTHLY MHRS FOR MC WORK [LUC 15] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[2] MONTHLY MHRS FOR OTHER W/O'S [LUC 18] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[3] MONTHLY MHRS FOR EMERGENCY J/O'S [LUC 12] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[4] MONTHLY MHRS FOR URGENT J/O'S [LUC 14] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[5] MONTHLY MHRS FOR ROUTINE J/O'S [LUC 16] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[6] MONTHLY MHRS FOR RECURRING WORK [LUC 11] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[7] MONTHLY MHRS FOR UTILITY OPS [LUC 19] - CURRENT MONTH ACTUAL MHRS, PCN SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

[8] MONTHLY TOTAL INDIRECT MHRS - CURRENT MONTH ACTUAL MHRS, PCN

03 06 ~~120000Z~~ 131915 APR 84 RR UUUU DEMG/3212

SF 100-252, BCE MONTHLY LABOR ANALYSIS REPORT

B. INPUT MEASUARES: TYPE DATA - SOURCE.

[1] NO. OF BENCH STOCK LINE ITEMS [COCESS/GOCESS PLUS BASE SUPPLY]; INCLUDES MFH - PCN SF 100-470, MRL LISTING AND/OR M24, ORGANIZATIONAL EFFECTIVENESS LISTING

[2] NO. OF WORK REQUESTS RECEIVED - AF FORM 1081, BCE WORK REQUEST/WORK ORDER REGISTER

[3] NO. OF JOB ORDERS RECEIVED - AF FORM 637, BCE JOB ORDER LOG

[4] NO. OF MATERIAL COMPLETE WORK ORDERS IN HOLDING AREA - LOCAL MONTHLY REPORT SUBMITTED TO PRODUCTION CONTROL [PCC]

[5] NO. OF MATERIAL COMPLETE JOB ORDERS IN HOLDING AREA - LOCAL MONTHLY REPORT SUBMITTED TO PCC

[6] NO. OF VEHICLES ASSIGNED TO THE OPERATIONS BRANCH - PCN N310024, VEHICLE MASTER LIST, SEE PARA 3A[1] AND 3D

[7] RATIO OF [NO. OF VEHICLES ASSIGNED DIVIDED BY NO. OF VEHICLES AUTHORIZED] TO THE OPERATIONS BRANCH - PCN N310024 AND BASE TRANSPORTATION SQUADRON, SEE PARA 3A[1] AND 3D.

[8] AVERAGE AGE OF VEHICLES ASSIGNED TO THE OPERATIONS BRANCH - PCN N310024, VEHICLE MASTER LIST, SEE PARA 3A[2] AND 3D

[9] NO. OF FILLED MILITARY POSITIONS WHERE ASSIGNED SKILL LEVEL IS

EQUAL TO OR GREATER THAN AUTHORIZED SKILL LEVEL [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[10] NO. OF FILLED MILITARY POSITIONS WHERE ASSIGNED GRADE IS EQUAL TO OR GREATER THAN AUTHORIZED GRADE [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[11] TOTAL ESTIMATED AVAILABLE MANHOURS - CURRENT MONTH ESTIMATED MHRS, PCN 100-252, BCE MONTHLY LABOR ANALYSIS REPORT, SEE PARA 3C

[12] NO. OF CIVILIANS ASSIGNED [EXLUDE OVERHIRES] [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[13] NO. OF OVERHIRES [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[14] RATIO OF [NO. OF CIVILIANS ASSIGNED DIVIDED BY NO. OF CIVILIANS AUTHORIZED] [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[15] NO. OF MILITARY ASSIGNED [OPERATIONS BRANCH ONLY] - LOCAL COUNT, PARA 3B AND 3D

[16] RATIO OF [NO. OF MILITARY ASSIGNED DIVIDED BY NO. OF MILITARY AUTHORIZED] [OPERATIONS BRANCH ONLY] - LOCAL COUNT 3B AND 3D

3. ADDITIONAL INFORMATION ON DATA COLLECTION PROCEDURES:

A. VEHICLES.

[1] INCLUDE ONLY "B" REGISTERED [THIRD POSITION OF REG. NO. EQUALS "B"] AND TELEPHONE MAINTENANCE VEHICLES. BOTH YOUR AUTHORIZED AND ASSIGNED COUNTS.

[2] DETERMINE AVERAGE AGE OF VEHICLES BY TOTALING AGES OF VEHICLES ASSIGNED [84 MINUS FIRST 2 POSITIONS OF REGISTRATION NO.] AND THEN DIVIDE BY THE TOTAL NO. OF VEHICLES ASSIGNED.

B. PERSONNEL.

[1] THE DATA REQUIRED CAN BE OBTAINED THROUGH AN APOLDS RETRIEVAL ON THE BEAMS FORCE RESOURCE MANAGEMENT [FRM] AND SHOP/COST CENTER WORKING LOGISTICS [SWL] FILES.

[2] FOR FRM FILE RETRIEVALS, COMPARE AUTHORIZED GRADE WITH ASSIGNED GRADE AND THE LAST TWO POSITIONS OF THE AUTHORIZED AFSC WITH THE LAST TWO POSITIONS OF THE PRIMARY AFSC FOR MILITARY ASSIGNED.

[3] INCLUDE ALL OPERATIONS BRANCH FUNCTIONS - SHOPS, RESOURCES AND REQUIREMENTS, READINESS AND LOGISTICS, ETC.

C. IF YOU DO NOT LOAD ESTIMATES FOR INDIRECT MANHOURS IN YOUR LABOR SUMMARY FILE [LSF], ADD TOTAL ACTUAL INDIRECT MHRS TO TOTAL ESTIMATED DIRECT MHRS FOR TOTAL ESTIMATED AVAILABLE MHRS.

D. FOR MAR 84 DATA ON PERSONNEL AND VEHICLES, BE SURE TO EXCLUDE

06 06 ~~120000Z~~ 131515 APR 84 RR UUUU DEMG/3212

ASSIGNED/AUTHORIZED GAINED IN APR 84.

4. REPORTING INFORMATION:

A. APPOINT A BASE PROJECT OFFICER, PREFERABLY IN INDUSTRIAL ENGINEERING.

B. SUBMIT DATA TO TAC/DEMG AS FOLLOWS:

	REPORT	NOT LATER THAN	VIA
[1]	CONFIRMATION OF MESSAGE RECEIPT, PROJ OFFICER NAME AND AUTOVON	20 APR 84	TELECON OR MSG
[2]	MAR 84 DATA	27 APR 84	MSG
[3]	APR 84 DATA	11 MAY 84	MSG
[4]	MAY 84 DATA	12 JUN 84	MSG

5. HQ TAC POINTS OF CONTACT ARE MAJ KOCHANEK/CMSGT GRUETER, AUTOVON 432-3212.

DEM/5846

Appendix D: Data File

```
MODEL EFF    OF AVAIL RES
   54    15    16
OUTPUT A   OUTPUT B   OUTPUT C   OUTPUT D   OUTPUT E   OUTPUT F   OUTPUT G.
OUTPUT 1   OUTPUT 2   OUTPUT 3   OUTPUT 4   OUTPUT 5   OUTPUT 6   OUTPUT 7
OUTPUT 8   INPUT 1    INPUT 2    INPUT 3    INPUT 4    INPUT 5    INPUT 6
INPUT 7    INPUT 8    INPUT 9    INPUT 10   INPUT 11   INPUT 12   INPUT 13
INPUT 14   INPUT 15   INPUT 16

   BERGSTROM1
0 BERGSTROM125560.  5527.    13297.   6746.    0.       0.       0.
1 BERGSTROM13139.   2388.    292.     2310.    10681.   6746.    0.
2 BERGSTROM18810.8  2736.    66.      1249.    44.      29.      39.
3 BERGSTROM11.08    .2183    98.      85.      29562.   88.      32.
4 BERGSTROM1.875    129.     .891
   BERGSTROM2
0 BERGSTROM224585.2 5125.9   11250.5  5688.8   0.       0.       0.
1 BERGSTROM22064.7  3861.2   288.6    2696.8   8273.1   5688.8   0.
2 BERGSTROM219691.3 2752.    55.      1152.    46.      13.      39.
3 BERGSTROM21.08    .2183    98.      85.      27683.   77.      33.
4 BERGSTROM2.875    134.     1.165
   BERGSTROM3
0 BERGSTROM327438.  6521.5   13574.9  7411.6   0.       0.       0.
1 BERGSTROM33755.0  1856.3   155.1    3031.8   10316.   7411.6   0.
2 BERGSTROM39755.5  2766.    47.      1228.    33.      10.      39.
3 BERGSTROM31.08    .218     97.      89.      25559.   78.      41.
4 BERGSTROM3.846    133.     1.157
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	CANNON1						
0	CANNON19986.8	332.5	5908.5	3845.9	0.	0.	0.
1	CANNON194.3	238.2	1019.6	1548.0	3241.	2836.3	1069.5
2	CANNON110649.9	2526.	17.	1561.	16.	28.	29.
3	CANNON1.93	.1284	139.	88.	23992.	74.	7.
4	CANNON1.987	137.	.94				
	CANNON2						
0	CANNON218734.2	1379.	11374.4	5989.8	0.	0.	0.
1	CANNON2917.5	452.5	1057.8	3075.6	7241.0	4450.	1535.9
2	CANNON29044.4	3526.	78.	1551.	34.	13.	29.
3	CANNON2.93	.1284	139.	88.	23430.3	70.	7.
4	CANNON2.987	137.	.94				
	CANNON3						
0	CANNON319020.2	1592.2	12061.4	5372.6	0.	0.	0.
1	CANNON3692.	900.2	1397.8	2518.3	8145.3	3819.	1553.6
2	CANNON310305.8	1679.	18.	2117.	46.	19.	28.
3	CANNON3.9	.133	138.	95.	25669.	72.	6.
4	CANNON3.973	139.	.95				
	DAVIS MON1						
0	DAVIS MON136381.9	5770.3	20266.4	10341.2	0.	0.	0.
1	DAVIS MON11067.5	4706.8	1339.5	4468.9	10467.	8282.3	2058.9
2	DAVIS MON113280.9	2598.	154.	1491.	48.	56.	48.
3	DAVIS MON11.	.1667	142.	111.	51779.	124.	67.
4	DAVIS MON1.87	164.	.72				
	DAVIS MON2						
0	DAVIS MON229291.1	6744.5	18788.1	10413.	0.	0.	0.
1	DAVIS MON21750.	4998.5	1353.5	4390.0	13044.2	8844.	2369.
2	DAVIS MON220958.	2643.	126.	1428.	49.	146.	48.
3	DAVIS MON21.	.1667	139.	147.	58819.	124.	67.
4	DAVIS MON2.87	164.	.77				
	DAVIS MON3						
0	DAVIS MON337224.	6126.	21436.	9662.	0.	0.	0.
1	DAVIS MON32207.	3919.	1447.	6164.	14275.	7270.	2392.
2	DAVIS MON323033.	2649.	174.	1622.	53.	130.	48.
3	DAVIS MON31.	.167	148.	115.	56731.	132.	54.

4	DAVIS MON3.93	176.	.92				
	ENGLAND1						
0	ENGLAND1 10551.9	912.	8710.1	4929.8	0.	0.	0.
1	ENGLAND1 193.	719.	521.	3315.6	4873.5	4354.8	575.
2	ENGLAND1 6326.1	1063.	13.	915.	73.	42.	31.
3	ENGLAND1 .861	.111	81.	66.	22792.7	196.	20.
4	ENGLAND1 .939	174.	.978				
	ENGLAND2						
0	ENGLAND2 16271.2	1116.2	10133.2	5021.8	0.	0.	0.
1	ENGLAND2 598.	518.2	575.8	4445.5	5111.9	4361.8	660.
2	ENGLAND2 9159.9	1033.	70.	889.	40.	70.	31.
3	ENGLAND2 .861	.111	136.	120.	27216.1	104.	26.
4	ENGLAND2 .912	174.	.978				
	ENGLAND3						
0	ENGLAND3 19850.3	1666.5	10136.3	6053.5	0.	0.	0.
1	ENGLAND3 559.	1107.5	458.2	5491.	4187.1	7508.5	545.
2	ENGLAND3 8259.2	1333.	51.	1039.	54.	83.	31.
3	ENGLAND3 .861	.111	129.	115.	28115.6	103.	27.
4	ENGLAND3 .90335	179.	1.0056				
	GEORGE1						
0	GEORGE1 24169.	4396.	10281.	9492.	0.	0.	0.
1	GEORGE1 1663.	2733.	1984.	4522.	4675.	8772.	720.
2	GEORGE1 1356.	2427.	81.	1915.	58.	65.	32.
3	GEORGE1 .91	.143	139.	89.	31058.	77.	23.
4	GEORGE1 .91	176.	.99				
	GEORGE2						
0	GEORGE2 24782.7	6596.3	8248.1	9938.3	0.	0.	0.
1	GEORGE2 2143.	4053.3	904.	2952.8	4395.3	9127.9	810.4
2	GEORGE2 19122.	2427.	99.	1215.	127.	75.	32.
3	GEORGE2 .91	.143	139.	89.	34097.	77.	23.
4	GEORGE2 .91	179.	.99				

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     GEORGE3
0    GEORGE327714.9 6465.9   14829.4 10419.6 0.      0.      0.
1    GEORGE32030.7  4035.2   1183.2  4141.8  5500.4  9715.6  784.
2    GEORGE311529.7 2427.    72.     1342.   81.     116.    32.
3    GEORGE3.92     .143     139.    80.     31911.  77.     23.
4    GEORGE3.91     176.     .94
     HOLLOMAN1
0    HOLLOMAN131763.3 2607.4 16803.  12352.9 0.      0.      0.
1    HOLLOMAN11134.9  1472.5 732.1   5752.0  10318.  8673.0  3679.
2    HOLLOMAN111379.1 1802.  56.     980.    36.     16.     45.
3    HOLLOMAN1.957    .125   174.    144.    43280.1 100.    10.
4    HOLLOMAN1.909    192.   .962
     HOLLOMAN2
0    HOLLOMAN229685.6 2863.2 15510.2 11515.2 0.      0.      0.
1    HOLLOMAN2502.9   2357.3 985.8   4516.5  10007.0 8017.1  3098.1
2    HOLLOMAN212693.8 1752.  71.     887.    29.     105.    47.
3    HOLLOMAN21.      .125   174.    149.    43076.8 104.    10.
4    HOLLOMAN2.95     206.   1.00
     HOLLOMAN3
0    HOLLOMAN331340.6 3693.  16658.1 10995.5 0.      0.      0.
1    HOLLOMAN31346.9  2346.1 1209.7  5819.0  9628.5  6393.1  2602.4
2    HOLLOMAN314727.5 1751.  97.     1271.   29.     140.    47.
3    HOLLOMAN31.      .143   174.    149.    46817.5 107.    10.
4    HOLLOMAN3.97     204.   1.03
     HOMESTEAD1
0    HOMESTEAD133536.   3526.5 18717.4 11292.1 0.      0.      0.
1    HOMESTEAD11739.5   1787.  1711.4  6896.2  10109.8 8280.1  3008.
2    HOMESTEAD110823.5  1225.  155.    2371.   40.     21.     52.
3    HOMESTEAD1.96      .150   290.    151.    40139.  198.    40.
4    HOMESTEAD1.92      207.   .98
     HOMESTEAD2
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0	HOMESTEAD238805.5	5812.5	21687.	11386.	0.	0.	0.
1	HOMESTEAD22588.	3300.5	2251.2	8437.1	10918.7	8396.5	2989.5
2	HOMESTEAD212306.5	1176.	188.	2682.	45.	33.	52.
3	HOMESTEAD2.96	.159	190.	157.	46760.5	108.	40.
4	HOMESTEAD2.92	282.	.96				
	HOMESTEAD3						
0	HOMESTEAD338254.6	8457.6	20050.1	9746.9	0.	0.	0.
1	HOMESTEAD35231.	3226.6	2515.5	6111.7	9422.9	6995.9	2751.
2	HOMESTEAD311647.	1186.	130.	2768.	35.	68.	52.
3	HOMESTEAD3.96	.159	197.	162.	48103.	108.	40.
4	HOMESTEAD3.92	294.	.97				
	HOWARD1						
0	HOWARD129123.1	2541.	18263.6	8318.5	0.	0.	0.
1	HOWARD1381.3	2159.7	964.1	8429.7	8869.8	5934.8	2383.7
2	HOWARD112607.	1348.	34.	2553.	11.	58.	28.
3	HOWARD1.85	.169	98.	83.	42417.	190.	0.
4	HOWARD1.95	98.	1.05				
	HOWARD2						
0	HOWARD225839.8	2600.6	15519.8	7719.4	0.	0.	0.
1	HOWARD21259.1	1340.5	771.8	7777.6	6970.4	5507.8	2211.6
2	HOWARD210270.3	1351.	38.	2429.	8.	47.	29.
3	HOWARD2.95	.169	98.	83.	39985.3	189.	0.
4	HOWARD2.95	94.	1.05				
	HOWARD3						
0	HOWARD326333.6	2018.	16680.4	7635.2	0.	0.	0.
1	HOWARD33528.	1490.	577.	7471.7	8631.7	5247.6	2387.6
2	HOWARD310629.5	1380.	22.	2494.	23.	53.	28.
3	HOWARD3.82	.154	97.	83.	40167.5	189.	5.
4	HOWARD3.95	98.	1.05				
	LANGLEY1						
0	LANGLEY142485.1	5687.5	24713.2	12084.4	0.	0.	0.
1	LANGLEY11561.	4126.5	4010.6	9673.3	11029.3	9936.0	2148.
2	LANGLEY122968.	2429.	108.	1975.	47.	145.	131.
3	LANGLEY1.978	.135	174.	187.	47708.	165.	57.
4	LANGLEY1.948	237.	.886				

	LANGLEY2						
0	LANGLEY240862.	6168.5	23402.	13291.5	0.	0.	0.
1	LANGLEY22621.3	5547.2	2903.	10792.1	9706.0	11178.5	2113.
2	LANGLEY219372.2	2052.	159.	2170.	42.	141.	131.
3	LANGLEY2.978	.135	189.	141.	66221.	169.	56.
4	LANGLEY2.960	220.	.091				
	LANGLEY3						
0	LANGLEY345422.9	6067.2	23413.3	15102.4	0.	0.	0.
1	LANGLEY32852.1	5615.1	2500.2	10082.3	10770.0	13510.	1620.4
2	LANGLEY320815.3	2051.	159.	2960.	76.	102.	131.
3	LANGLEY3.978	.135	187.	137.	60705.	170.	53.
4	LANGLEY3.966	210.	1.029				
	LUKE1						
0	LUKE125753.7	5658.8	13597.3	6497.6	0.	0.	0.
1	LUKE11780.	4074.8	460.2	3065.1	9672.	3496.4	3901.2
2	LUKE113624.	1127.	82.	1042.	40.	56.	49.
3	LUKE1.976	.192	111.	83.	49466.	98.	15.
4	LUKE1.933	170.	.955				
	LUKE2						
0	LUKE226717.1	6287.6	13659.8	6769.7	0.	0.	0.
1	LUKE22885.5	3402.1	243.4	4398.8	9017.6	3922.2	2847.5
2	LUKE210945.5	1127.	52.	1159.	52.	69.	40.
3	LUKE2.976	.196	106.	85.	36536.5	98.	19.
4	LUKE2.933	168.	.944				
	LUKE3						
0	LUKE329997.3	6734.8	16361.7	6909.8	0.	0.	0.
1	LUKE31943.	4891.8	332.2	4617.1	11412.4	3662.3	3238.5

2	LUKE310605.	1127.	36.	1558.	55.	57.	41.
3	LUKE31.	.208	98.	80.	37472.	97.	23.
4	LUKE3.928	168.	.948				
	MACDILL1						
0	MACDILL134683.	3632.3	18310.5	12788.2	0.	0.	0.
1	MACDILL12961.0	1579.9	553.	2466.6	15290.9	8461.7	4278.5
2	MACDILL110592.9	1092.	197.	2040.	8.	99.	37.
3	MACDILL1.973	.208	163.	110.	45348.9	135.	28.
4	MACDILL1.979	203.	.976				
	MACDILL2						
0	MACDILL236933.9	4882.3	18859.9	13191.7	0.	0.	0.
1	MACDILL22547.2	2335.1	592.2	2458.5	15699.2	9068.7	4187.
2	MACDILL214592.9	1090.	140.	1069.	29.	107.	38.
3	MACDILL21.	.2	179.	115.	49136.4	144.	37.
4	MACDILL2.947	207.	.967				
	MACDILL3						
0	MACDILL340403.3	5707.3	29887.2	13808.8	0.	0.	0.
1	MACDILL32212.7	3494.6	691.1	2897.4	17298.7	9210.8	4598.
2	MACDILL316535.4	1092.	56.	2067.	19.	147.	38.
3	MACDILL31.	.20	175.	129.	55172.4	133.	38.
4	MACDILL3.887	207.	.949				
	MOODY1						
0	MOODY121568.8	2251.7	10932.3	8388.8	0.	0.	0.
1	MOODY1561.2	1690.5	1111.2	2590.8	7230.3	8087.8	297.
2	MOODY16326.3	2246.	74.	1225.	26.	144.	29.
3	MOODY11.	.161	46.	40.	22310.	53.	17.
4	MOODY1.93	64.	1.067				
	MOODY2						
0	MOODY217709.	2507.8	8877.1	6410.1	0.	0.	0.
1	MOODY2846.6	1661.2	742.4	2350.2	5775.5	6229.6	184.5
2	MOODY211022.4	2246.	75.	1909.	26.	139.	20.
3	MOODY21.	.161	47.	42.	25620.3	53.	17.
4	MOODY2.93	65.	1.083				

	MOODY3						
0	MOODY320331.	1782.6	11209.8	7338.6	0.	0.	0.
1	MOODY3344.1	1433.5	683.2	2768.1	7558.5	7157.6	181.
2	MOODY35469.5	2246.	76.	1317.	34.	120.	24.
3	MOODY31.	.161	48.	41.	37058.	53.	17.
4	MOODY3.93	64.	1.067				
	M HOME1						
0	M HOME128179.4	2371.9	9822.5	15985.	0.	0.	0.
1	M HOME11143.5	1228.4	554.3	4269.	4990.2	10457.	5528.
2	M HOME112645.5	865.	84.	1120.	20.	127.	116.
3	M HOME11.	.167	134.	114.	39685.	123.	6.
4	M HOME1.97	159.	.97				
	M HOME2						
0	M HOME227739.9	2531.2	10391.	14907.7	0.	0.	0.
1	M HOME21237.1	1294.1	589.8	4123.2	5588.	10186.8	4720.0
2	M HOME212164.4	666.	48.	1121.	43.	149.	116.
3	M HOME21.	.167	128.	111.	38112.	123.	34.
4	M HOME2.97	157.	.96				
	M HOME3						
0	M HOME329677.5	3028.2	8624.2	18025.1	0.	0.	0.
1	M HOME3891.5	2136.7	656.7	3267.6	4690.0	14001.5	3933.6
2	M HOME317683.7	866.	42.	1167.	68.	135.	116.
3	M HOME31.	.167	127.	110.	46609.	124.	34.
4	M HOME3.96	156.	.95				
	MYRTLE B1						
0	MYRTLE B119568.7	4717.1	11150.1	3701.5	0.	0.	0.
1	MYRTLE B11668.8	3848.3	1716.6	2149.7	7283.8	3674.5	27.
2	MYRTLE B11668.8	1222.	195.	1180.	137.	111.	77.
3	MYRTLE B1.93	.130	14.	14.	25380.	116.	20.

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4  MYRTLE B1.88      109.     .87
   MYRTLE B2
0  MYRTLE B219786.3 4742.0   10126.7 3956.7  0.       0.      0.
1  MYRTLE B2989.6   1713.1   1340.5  1482.7  7303.5   3956.7  0.
2  MYRTLE B27930.2  1940.    120.    730.    193.     71.     77.
3  MYRTLE B2.93     .130     10.     10.     20922.   117.    33.
4  MYRTLE B2.89     110.     .89
   MYRTLE B3
0  MYRTLE B315316.9 2165.7   8496.   4655.2  0.       0.      0.
1  MYRTLE B31268.4  897.3    1230.   1510.   5756.    4630.   25.2
2  MYRTLE B314538.5 1107.    57.     1215.   109.     118.    76.
3  MYRTLE B3.93     .130     10.     10.     20644.   115.    33.
4  MYRTLE B3.87     107.     .88
     NELLTS1
0    NELLTS137833.1 8655.9   19166.2 10011.  0.       0.      0.
1    NELLTS17193.2  1462.7   7479.1  1680.   10093.1  6552.6  3458.4
2    NELLTS114114.4 2079.    78.     1432.   84.      188.    52.
3    NELLTS1.897    .223     229.    180.    29786.   60.     44.
4    NELLTS1.732    243.     .946
     NELLTS2
0    NELLTS233157.9 6302.6   17186.1 9669.2  0.       0.      0.
1    NELLTS21726.1  4576.5   1390.3  6473.3  9318.5   6643.1  3026.1
2    NELLTS217924.6 2079.    69.     1367.   191.     140.    52.
3    NELLTS2.897    .223     229.    180.    29786.   69.     44.
4    NELLTS2.732    243.     .946
     NELLTS3
0    NELLTS333068.8 4096.0   19199.6 9862.3  0.       0.      0.
1    NELLTS3900.5   3196.4   1562.9  8666.7  8860.    6396.3  3466.
2    NELLTS315331.1 2079.    66.     1965.   61.      96.     52.
3    NELLTS3.89655  .227     229.    243.    31454.   77.     59.
4    NELLTS3.7417   243.     .0455
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	SEY	JOHN1						
0	SEY	JOHN124818.4	3530.6	12479.0	8817.2	0.	0.	0.
1	SEY	JOHN12168.1	1362.5	1254.3	4174.9	7939.4	4945.2	3872.
2	SEY	JOHN118463.2	572.	159.	1125.	49.	41.	51.
3	SEY	JOHN1.944	.179	144.	121.	34355.5	65.	0.
4	SEY	JOHN1.924	178.	.947				
	SEY	JOHN2						
0	SEY	JOHN225945.	3833.	11166.5	10945.5	0.	0.	0.
1	SEY	JOHN21253.	2587.	1068.9	4099.3	5987.3	7354.8	3599.7
2	SEY	JOHN215310.4	572.	92.	1083.	49.	41.	51.
3	SEY	JOHN2.944	.179	149.	123.	20980.5	85.	0.
4	SEY	JOHN2.924	183.	.973				
	SEY	JOHN3						
0	SEY	JOHN328072.6	3601.6	12689.9	11781.1	0.	0.	0.
1	SEY	JOHN3706.7	2894.9	1150.5	5047.1	6088.3	8378.8	3402.3
2	SEY	JOHN312966.2	572.	192.	1479.	38.	74.	51.
3	SEY	JOHN31.02	.176	153.	134.	28260.	84.	0.
4	SEY	JOHN3.923	188.	1.01				
		SHAW1						
0		SHAW127599.	6253.	13520.4	7735.6	0.	0.	0.
1		SHAW13725.7	3227.3	889.	4228.6	8402.8	4326.9	3408.7
2		SHAW112450.9	1868.	106.	1296.	28.	6.	38.
3		SHAW11.	.151	130.	85.	36294.9	67.	6.
4		SHAW1.968	211.	1.094				
		SHAW2						
0		SHAW224962.	6932.7	11298.1	7721.2	0.	0.	0.
1		SHAW22039.7	3093.	1913.3	3269.8	6930.	4482.1	3239.1
2		SHAW211794.3	1868.	220.	1201.	24.	35.	38.
3		SHAW21.	.162	130.	93.	36306.3	74.	5.
4		SHAW2.925	192.	1.005				
		SHAW3						

0	SHAW324124.	4615.	9016.	9593.	0.	0.	0.
1	SHAW31390.	3225.	671.	2852.	6393.	6954.	3539.
2	SHAW35735.	1869.	159.	1316.	39.	99.	38.
3	SHAW31.	.162	141.	101.	29859.	73.	11.
4	SHAW31.077	185.	.959				
	TYNDALL1						
0	TYNDALL136697.4	4050.	17095.	14662.4	0.	0.	0.
1	TYNDALL11579.5	3371.5	1418.	5721.2	9945.8	11713.4	3280.
2	TYNDALL118335.	1733.	159.	1383.	39.	58.	62.
3	TYNDALL1.969	.190	297.	156.	47156.	111.	50.
4	TYNDALL1.94	190.	.974				
	TYNDALL2						
0	TYNDALL236126.2	4368.3	17462.1	14295.8	0.	0.	0.
1	TYNDALL23187.9	1180.5	1342.3	5571.6	19546.2	11346.8	2949.
2	TYNDALL214749.9	1733.	124.	1279.	36.	71.	62.
3	TYNDALL2.969	.190	297.	156.	43862.	111.	52.
4	TYNDALL2.94	196.	.974				
	TYNDALL3						
0	TYNDALL339133.2	6144.5	17192.2	14806.5	0.	0.	0.
1	TYNDALL32264.5	3890.	2334.9	5168.2	9679.1	11731.	3975.5
2	TYNDALL315570.8	1867.	95.	1438.	41.	55.	69.
3	TYNDALL3.938	.19	298.	153.	47987.	110.	51.
4	TYNDALL3.932	188.	.964				

Appendix E: Summary File

1		MODEL EFF	OF AVAIL RES					
2		54	4	7				
3		OUTPUT B	OUTPUT C	OUTPUT D	OUTPUT 8	INPUT 1	INPUT 3	INPUT 5
4		INPUT 9	INPUT 11	INPUT 13	INPUT 15			
0	BERGSTROM1						.87406	.97690
1	BERGSTROM1	5527.000	13287.000	6746.000	8810.800	2736.000	1249.000	39.000
2	BERGSTROM1	.000031	.000032	.000008	.000026	.000044	.000062	.006933
3	BERGSTROM1	0	0	0	0	0	0	0
4	BERGSTROM1	98.000	29562.000	32.000	129.000			
5	BERGSTROM1	.001822	.000015	0	0			
6	BERGSTROM1	0	0	12.604	1.999			
0	BERGSTROM2						.85386	.93258
1	BERGSTROM2	5125.900	11250.500	5688.800	10691.300	2752.000	1152.000	39.000
2	BERGSTROM2	.000070	.000010	.000043	.000013	.000018	.000283	.002532
3	BERGSTROM2	0	0	0	0	0	0	0
4	BERGSTROM2	98.000	27683.000	33.000	134.000			
5	BERGSTROM2	.002547	.000002	.002704	.000991			
6	BERGSTROM2	0	0	0	0			
0	BERGSTROM3						1.00000	1.00000
1	BERGSTROM3	6521.500	13504.900	7411.600	9755.500	2766.000	1228.000	39.000
2	BERGSTROM3	.000009	.000054	.000000	.000022	.000041	.000082	.002998
3	BERGSTROM3	0	0	0	0	0	0	0
4	BERGSTROM3	97.000	25559.000	41.000	133.000			
5	BERGSTROM3	.002292	.000017	.000010	.000001			
6	BERGSTROM3	0	0	0	0			
0	CANNON1						1.00000	1.00000
1	CANNON1	332.500	5808.500	3845.800	10649.900	2526.000	1561.000	9.000
2	CANNON1	.000000	.000000	.000000	.000094	.000000	.000000	.111025
3	CANNON1	0	0	0	0	0	0	0
4	CANNON1	139.000	23992.000	7.000	137.000			
5	CANNON1	.000001	.000000	.000010	.000001			
6	CANNON1	0	0	0	0			

0	CANNON2						.56821	.98210
1	CANNON2	1370.000	11374.400	5989.800	9044.400	3526.000	1551.000	29.000
2	CANNON2	.000045	.000031	.000028	0	.000099	0	.003580
3	CANNON2	0	0	0	250.608	0	138.961	0
4	CANNON2	139.000	23430.300	7.000	137.000			
5	CANNON2	.000397	.000012	.000451	.001569			
6	CANNON2	0	0	0	0			
0	CANNON3						.86298	.99619
1	CANNON3	1592.200	12061.400	5372.600	10305.800	1679.000	2117.000	28.000
2	CANNON3	.000020	.000035	.000016	.000031	.000044	.000032	.011430
3	CANNON3	0	0	0	0	0	0	0
4	CANNON3	138.000	25669.000	6.000	139.000			
5	CANNON3	.001018	.000016	0	0			
6	CANNON3	0	0	2.159	11.034			
0	DAVIS MON1						1.00000	1.00000
1	DAVIS MON1	5774.300	20266.400	10341.200	18280.900	2598.000	1491.000	48.000
2	DAVIS MON1	.000022	.000025	.000019	.000009	.000074	.000068	.000019
3	DAVIS MON1	0	0	0	0	0	0	0
4	DAVIS MON1	142.000	51779.000	67.000	164.000			
5	DAVIS MON1	.000565	.000005	.000010	.002161			
6	DAVIS MON1	0	0	0	0			
0	DAVIS MON2						1.00000	1.00000
1	DAVIS MON2	6744.500	18788.100	10413.000	20958.000	2643.000	1428.000	48.000
2	DAVIS MON2	.000051	.000011	.000000	.000022	.000060	.000000	.000710
3	DAVIS MON2	0	0	0	0	0	0	0
4	DAVIS MON2	139.000	54819.000	67.000	164.000			
5	DAVIS MON2	.000558	.000008	.000010	.001785			
6	DAVIS MON2	0	0	0	0			
0	DAVIS MON3						1.00000	1.00000

1	DAVIS MUN3	6126.000	21436.000	9662.000	23033.000	2649.000	1622.000	48.000
2	DAVIS MUN3	.000029	.000038	.000000	.000001	.000000	.000206	.000010
3	DAVIS MUN3	0	0	0	0	0	0	0
4	DAVIS MUN3	148.000	56731.000	54.000	176.000			
5	DAVIS MUN3	.000308	.000000	.004400	.002170			
6	DAVIS MUN3	0	0	0	0			
0	ENGLAND1						.58985	.62556
1	ENGLAND1	912.000	8710.100	4929.800	6326.100	1063.000	915.000	31.000
2	ENGLAND1	.000035	.000050	.000020	.000004	.000072	.000238	0
3	ENGLAND1	0	0	0	0	0	0	49.550
4	ENGLAND1	81.000	22782.700	24.000	174.000			
5	ENGLAND1	0	.000006	.002064	.002942			
6	ENGLAND1	30.602	0	0	0			
0	ENGLAND2						.73379	.69148
1	ENGLAND2	1116.200	10133.200	5021.800	9159.900	1033.000	889.000	31.000
2	ENGLAND2	.000031	.000054	.000007	.000014	.000067	.000240	.006281
3	ENGLAND2	0	0	0	0	0	0	0
4	ENGLAND2	136.000	27216.100	26.000	174.000			
5	ENGLAND2	0	.000006	.004567	.001317			
6	ENGLAND2	93.710	0	0	0			
0	ENGLAND3						.74291	.87749
1	ENGLAND3	1666.500	10136.300	8053.500	8259.200	1333.000	1030.000	31.000
2	ENGLAND3	.000018	.000008	.000055	.000023	.000008	.000139	.017894
3	ENGLAND3	0	0	0	0	0	0	0
4	ENGLAND3	129.000	28115.600	27.000	179.000			
5	ENGLAND3	.000081	.000001	.008901	0			
6	ENGLAND3	0	0	0	10.626			
0	GEORGE1						1.00000	1.00000
1	GEORGE1	4396.000	10281.000	9492.000	13560.000	2427.000	1015.000	32.000
2	GEORGE1	.000059	.000015	.000054	.000005	.000000	.000506	.003635
3	GEORGE1	0	0	0	0	0	0	0
4	GEORGE1	139.000	31056.000	23.000	176.000			
5	GEORGE1	.001543	.000005	.000010	.000001			
6	GEORGE1	0	0	0	0			

0	GEORGE2						1.00000	1.00000
1	GEORGE2	6596.300	8248.100	9938.300	10122.000	2427.000	1215.000	32.000
2	GEORGE2	.000086	.000001	.000042	.000000	.000000	.000799	.000080
3	GEORGE2	0	0	0	0	0	0	0
4	GEORGE2	139.000	34697.000	23.000	176.000			
5	GEORGE2	.000001	.000000	.000010	.000001			
6	GEORGE2	0	0	0	0			
0	GEORGE3						1.00000	1.00000
1	GEORGE3	6465.900	10829.400	10419.600	11529.700	2427.000	1342.000	32.000
2	GEORGE3	.000069	.000000	.000053	.000000	.000000	.000031	.013243
3	GEORGE3	0	0	0	0	0	0	0
4	GEORGE3	139.000	31911.000	23.000	176.000			
5	GEORGE3	.001696	.000000	.012962	.000001			
6	GEORGE3	0	0	0	0			
0	HOLLOMAN1						1.00000	1.00000
1	HOLLOMAN1	2607.400	16803.000	12352.900	11379.100	1802.000	980.000	45.000
2	HOLLOMAN1	.000027	.000050	.000000	.000008	.000023	.000222	.000010
3	HOLLOMAN1	0	0	0	0	0	0	0
4	HOLLOMAN1	170.000	43286.100	10.000	192.000			
5	HOLLOMAN1	.000001	.000006	.004791	.002181			
6	HOLLOMAN1	0	0	0	0			
0	HOLLOMAN2						1.00000	1.00000
1	HOLLOMAN2	2860.200	15510.200	11515.200	12693.800	1752.000	887.000	47.000
2	HOLLOMAN2	.000106	.000015	.000040	.000000	.000120	.000872	.000010
3	HOLLOMAN2	0	0	0	0	0	0	0
4	HOLLOMAN2	174.000	43076.800	10.000	206.000			
5	HOLLOMAN2	.000001	.000000	.001475	.000001			
6	HOLLOMAN2	0	0	0	0			

0	HOLLUMAN3						.97087	.99767
1	HOLLUMAN3	3693.000	16658.100	10995.500	14727.500	1751.000	1271.000	47.000
2	HOLLUMAN3	.000024	.000029	.000015	.000016	.000013	.000169	.007573
3	HOLLUMAN3	0	0	0	0	0	0	0
4	HOLLUMAN3	174.000	46817.500	10.000	204.000			
5	HOLLUMAN3	.000695	.000004	.004410	.000375			
6	HOLLUMAN3	0	0	0	0			
0	HOMESTEAD1						.91972	.91972
1	HOMESTEAD1	3526.500	18717.400	11292.100	10823.500	1225.000	2371.000	52.000
2	HOMESTEAD1	.000000	.000040	.000015	.000000	.000085	.000040	.004086
3	HOMESTEAD1	1550.626	0	0	3021.610	0	0	0
4	HOMESTEAD1	200.000	44139.000	40.000	207.000			
5	HOMESTEAD1	.000001	.000011	.000010	.000403			
6	HOMESTEAD1	12.552	0	11.231	0			
0	HOMESTEAD2						1.00000	1.00000
1	HOMESTEAD2	5812.500	21607.000	11386.000	12306.500	1176.000	2682.000	52.000
2	HOMESTEAD2	.000032	.000031	.000013	.000000	.000149	.000000	.005558
3	HOMESTEAD2	0	0	0	0	0	0	0
4	HOMESTEAD2	190.000	46764.500	40.000	202.000			
5	HOMESTEAD2	.000001	.000011	.000010	.000001			
6	HOMESTEAD2	0	0	0	0			
0	HOMESTEAD3						1.00000	1.00000
1	HOMESTEAD3	8457.600	20050.100	9746.900	11647.000	1186.000	2788.000	52.000
2	HOMESTEAD3	.000075	.000010	.000013	.000002	.000050	.000000	.000010
3	HOMESTEAD3	0	0	0	0	0	0	0
4	HOMESTEAD3	197.000	48103.000	40.000	204.000			
5	HOMESTEAD3	.000001	.000000	.000010	.004606			
6	HOMESTEAD3	0	0	0	0			
0	HOWARD1						1.00000	1.00000
1	HOWARD1	2541.000	18263.600	8318.500	12607.000	1348.000	2553.000	28.000
2	HOWARD1	.000033	.000029	.000047	.000000	.000347	.000000	.001077
3	HOWARD1	0	0	0	0	0	0	0
4	HOWARD1	98.000	42417.000	0	98.000			
5	HOWARD1	.005112	.000000	.003487	.000001			
6	HOWARD1	0	0	0	0			

0	HOWARD2						1.00000	1.00000
1	HOWARD2	2600.600	15519.800	7719.400	10270.300	1351.000	2429.000	29.000
2	HOWARD2	.000135	.000000	.000084	.000000	.000000	.000000	.000010
3	HOWARD2	0	0	0	0	0	0	0
4	HOWARD2	98.000	39985.300	0	94.000			
5	HOWARD2	.000001	.000000	.019373	.010609			
6	HOWARD2	0	0	0	0			
0	HOWARD3						.88347	.95168
1	HOWARD3	2018.000	16680.400	7635.200	10629.500	1389.000	2494.000	28.000
2	HOWARD3	.000077	.000018	.000026	.000022	.000064	0	.000149
3	HOWARD3	0	0	0	0	0	135.612	0
4	HOWARD3	97.000	40167.500	5.000	98.000			
5	HOWARD3	.000618	.000011	.001697	.001913			
6	HOWARD3	0	0	0	0			
0	LANGLEY1						1.00000	1.00000
1	LANGLEY1	5687.500	24713.200	12084.400	22968.000	2429.000	1975.000	131.000
2	LANGLEY1	.000012	.000028	.000006	.000008	.000050	.000261	.000010
3	LANGLEY1	0	0	0	0	0	0	0
4	LANGLEY1	174.000	47708.000	57.000	237.000			
5	LANGLEY1	.000001	.000004	.000010	.000612			
6	LANGLEY1	0	0	0	0			
0	LANGLEY2						.85188	.96321
1	LANGLEY2	8168.500	23402.000	13291.500	19372.200	2952.000	2170.000	131.000
2	LANGLEY2	.000027	.000017	.000014	.000003	.000024	.000127	.001503
3	LANGLEY2	0	0	0	0	0	0	0
4	LANGLEY2	189.000	66221.000	56.000	220.000			
5	LANGLEY2	.000097	.000002	.001436	.001155			

6	LANGLEY2	0	0	0	0			
0	LANGLEY3						.87220	.92933
1	LANGLEY3	6467.200	23413.300	15142.400	20815.300	2951.000	2960.000	131.000
2	LANGLEY3	.000051	.000004	.000018	.000009	.000048	.000010	.000731
3	LANGLEY3	0	0	0	0	0	0	0
4	LANGLEY3	187.000	60705.000	53.000	216.000			
5	LANGLEY3	.000084	.000003	.001077	.002330			
6	LANGLEY3	0	0	0	0			
0	LUKE1						1.00000	1.00000
1	LUKE1	5058.800	13597.300	6497.600	13624.000	1127.000	1042.000	40.000
2	LUKE1	.000026	.000055	.000000	.000008	.000071	.000306	.000010
3	LUKE1	0	0	0	0	0	0	0
4	LUKE1	111.000	40466.000	15.000	170.000			
5	LUKE1	.000255	.000006	.003285	.001575			
6	LUKE1	0	0	0	0			
0	LUKE2						1.00000	1.00000
1	LUKE2	6287.600	13659.800	6769.700	10945.500	1127.000	1159.000	40.000
2	LUKE2	.000096	.000000	.000033	.000016	.000086	.000068	.002915
3	LUKE2	0	0	0	0	0	0	0
4	LUKE2	106.000	36536.500	19.000	168.000			
5	LUKE2	.000041	.000000	.003367	.003814			
6	LUKE2	0	0	0	0			
0	LUKE3						1.00000	1.00000
1	LUKE3	6734.800	16361.700	6900.800	10695.000	1127.000	1554.000	41.000
2	LUKE3	.000103	.000002	.000040	.000000	.000069	.000000	.000010
3	LUKE3	0	0	0	0	0	0	0
4	LUKE3	98.000	37472.000	23.000	168.000			
5	LUKE3	.000450	.000006	.003836	.003420			
6	LUKE3	0	0	0	0			

0	MACDILL1						1.00000	1.00000
1	MACDILL1	3632.300	18310.500	12740.200	14502.900	1090.000	2040.000	37.000
2	MACDILL1	.000000	.000000	.000078	.000000	.000122	.000000	.010114
3	MACDILL1	0	0	0	0	0	0	0
4	MACDILL1	163.000	45348.900	28.000	203.000			
5	MACDILL1	.002211	.000000	.004716	.000001			
6	MACDILL1	0	0	0	0			
0	MACDILL2						1.00000	1.00000
1	MACDILL2	4882.300	18859.900	13191.700	14502.900	1090.000	1969.000	38.000
2	MACDILL2	.000015	.000000	.000067	.000003	.000074	.000000	.011519
3	MACDILL2	0	0	0	0	0	0	0
4	MACDILL2	179.000	49136.400	37.000	207.000			
5	MACDILL2	.000001	.000010	.000010	.000001			
6	MACDILL2	0	0	0	0			
0	MACDILL3						1.00000	1.00000
1	MACDILL3	5707.300	20887.200	13808.800	16535.400	1092.000	2067.000	38.000
2	MACDILL3	.000104	.000000	.000010	.000016	.000654	.000000	.007502
3	MACDILL3	0	0	0	0	0	0	0
4	MACDILL3	175.000	55172.400	38.000	207.000			
5	MACDILL3	.000001	.000000	.000010	.000001			
6	MACDILL3	0	0	0	0			
0	MOODY1						1.00000	1.00000
1	MOODY1	2251.700	10932.300	8384.000	6326.300	2246.000	1225.000	20.000
2	MOODY1	.000000	.000038	.000048	.000028	.000003	.000464	.001572
3	MOODY1	0	0	0	0	0	0	0
4	MOODY1	46.000	22310.000	17.000	64.000			
5	MOODY1	.004927	.000003	.005866	.000001			
6	MOODY1	0	0	0	0			
0	MOODY2						1.00000	1.00000
1	MOODY2	2507.800	8877.100	6414.100	11022.400	2246.000	1099.000	20.000
2	MOODY2	.000000	.000036	.000029	.000045	.000000	.000544	.004453
3	MOODY2	0	0	0	0	0	0	0
4	MOODY2	47.000	25620.300	17.000	65.000			

5	MOODY2	.006662	.000000	.000010	.000001			
6	MOODY2	0	0	0	0			
0	MOODY3						1.00000	1.00000
1	MOODY3	1782.600	11209.800	7338.600	5469.500	2246.000	1317.000	20.000
2	MOODY3	.000000	.000085	.000000	.000008	.000000	.000000	.029802
3	MOODY3	0	0	0	0	0	0	0
4	MOODY3	48.000	37058.000	17.000	64.000			
5	MOODY3	.008403	.000000	.000010	.000001			
6	MOODY3	0	0	0	0			
0	M HOME1						1.00000	1.00000
1	M HOME1	2371.900	9822.500	15985.000	12645.500	865.000	1120.000	116.000
2	M HOME1	.000103	.000000	.000047	.000000	.000076	.000000	.000010
3	M HOME1	0	0	0	0	0	0	0
4	M HOME1	130.000	39685.000	6.000	159.000			
5	M HOME1	.000001	.000000	.006455	.005624			
6	M HOME1	0	0	0	0			
0	M HOME2						1.00000	1.00000
1	M HOME2	2531.200	10301.000	14907.700	12164.400	866.000	1121.000	116.000
2	M HOME2	.000000	.000045	.000036	.000000	.000098	.000207	.000010
3	M HOME2	0	0	0	0	0	0	0
4	M HOME2	128.000	38112.000	34.000	157.000			
5	M HOME2	.001150	.000008	.000010	.001571			
6	M HOME2	0	0	0	0			
0	M HOME3						1.00000	1.00000
1	M HOME3	3028.200	8624.200	18025.100	17683.700	866.000	1167.000	116.000
2	M HOME3	.000025	.000036	.000034	.000000	.000101	.000163	.000010
3	M HOME3	0	0	0	0	0	0	0
4	M HOME3	127.000	46699.000	34.000	156.000			
5	M HOME3	.000856	.000006	.000010	.002079			
6	M HOME3	0	0	0	0			

0	MYRTLE B1						1.00000	1.00000	
1	MYRTLE B1	4717.100	11150.100	3701.500	1668.000	1222.000	1180.000	77.000
2	MYRTLE B1	.000000	.000090	.000000	.000000	.000021	.000404	.003554
3	MYRTLE B1	0	0	0	0	0	0	0
4	MYRTLE B1	14.000	25380.000	20.000	109.000			
5	MYRTLE B1	.004921	.000000	.008506	.000001			
6	MYRTLE B1	0	0	0	0			
0	MYRTLE B2						1.00000	1.00000
1	MYRTLE B2	4702.900	10126.700	3956.700	7930.200	1040.000	730.000	77.000
2	MYRTLE B2	.000037	.000057	.000062	.000000	.000000	.000717	.000010
3	MYRTLE B2	0	0	0	0	0	0	0
4	MYRTLE B2	14.000	24922.000	33.000	110.000			
5	MYRTLE B2	.002034	.000000	.000010	.004064			
6	MYRTLE B2	0	0	0	0			
0	MYRTLE B3						1.00000	1.00000
1	MYRTLE B3	2165.700	8496.000	4655.200	14538.500	1107.000	1215.000	76.000
2	MYRTLE B3	.000017	.000035	.000143	.000000	.000000	.000000	.000016
3	MYRTLE B3	0	0	0	0	0	0	0
4	MYRTLE B3	14.000	24844.000	33.000	107.000			
5	MYRTLE B3	.071325	.000000	.000010	.000001			
6	MYRTLE B3	0	0	0	0			
0	NELLIS1						1.00000	1.00000
1	NELLIS1	8655.900	19166.200	10011.000	14114.400	2479.000	1432.000	52.000
2	NELLIS1	.000025	.000021	.000015	.000017	.000000	.000070	.010069
3	NELLIS1	0	0	0	0	0	0	0
4	NELLIS1	229.000	29746.000	44.000	243.000			
5	NELLIS1	.000001	.000007	.003513	.000001			
6	NELLIS1	0	0	0	0			
0	NELLIS2						1.00000	1.00000
1	NELLIS2	6302.600	17186.100	9669.200	17920.600	2479.000	1367.000	52.000
2	NELLIS2	.000007	.000029	.000015	.000018	.000000	.000155	.009216
3	NELLIS2	0	0	0	0	0	0	0

4	NELLIS2	229.000	29746.000	44.000	243.000			
5	NELLIS2	.000001	.000007	.002341	.000001			
6	NELLIS2	0	0	0	0			
0	NELLIS3						.84695	.99567
1	NELLIS3	4096.900	19109.600	9862.300	15331.100	2479.000	1865.000	52.000
2	NELLIS3	.000033	.000014	.000003	.000027	.000028	.000021	.010516
3	NELLIS3	0	0	0	0	0	0	0
4	NELLIS3	229.000	31454.000	50.000	243.000			
5	NELLIS3	0	.000008	.002153	0			
6	NELLIS3	89.918	0	0	99.810			
0	SEY JOHN1						1.00000	1.00000
1	SEY JOHN1	3530.600	12470.600	8817.200	18463.200	572.000	1125.000	51.000
2	SEY JOHN1	.000000	.000032	.000000	.000032	.000000	.000106	.010240
3	SEY JOHN1	0	0	0	0	0	0	0
4	SEY JOHN1	144.000	34355.500	0	178.000			
5	SEY JOHN1	.000001	.000010	.003402	.000001			
6	SEY JOHN1	0	0	0	0			
0	SEY JOHN2						1.00000	1.00000
1	SEY JOHN2	3633.000	11166.500	10945.500	15310.400	572.000	1683.000	51.000
2	SEY JOHN2	.000162	.000030	.000000	.000003	.000000	.000000	.000010
3	SEY JOHN2	0	0	0	0	0	0	0
4	SEY JOHN2	149.000	20980.500	0	183.000			
5	SEY JOHN2	.000134	.000000	9.791971	.000001			
6	SEY JOHN2	0	0	0	0			
0	SEY JOHN3						1.00000	1.00000
1	SEY JOHN3	3601.600	12689.900	11781.100	12966.200	572.000	1470.000	51.000
2	SEY JOHN3	.000000	.000053	.000027	.000000	.000730	.000269	.003060
3	SEY JOHN3	0	0	0	0	0	0	0
4	SEY JOHN3	153.000	28260.000	0	188.000			
5	SEY JOHN3	.000001	.000000	.000010	.000001			
6	SEY JOHN3	0	0	0	0			

0	SHAW1						1.00000	1.00000
1	SHAW1	6253.000	13520.400	7735.600	12450.900	1868.000	1296.000	38.000
2	SHAW1	.000048	.000016	.000005	.000035	.000037	.000022	.014043
3	SHAW1	0	0	0	0	0	0	0
4	SHAW1	130.000	36294.900	6.000	211.000			
5	SHAW1	.000001	.000010	.003125	.000001			
6	SHAW1	0	0	0	0			
0	SHAW2						1.00000	1.00000
1	SHAW2	6032.700	11208.100	7721.200	11780.300	1868.000	1201.000	38.000
2	SHAW2	.000088	.000019	.000033	.000000	.000005	.000525	.006464
3	SHAW2	0	0	0	0	0	0	0
4	SHAW2	130.000	36306.300	5.000	192.000			
5	SHAW2	.000001	.000000	.005658	.000445			
6	SHAW2	0	0	0	0			
0	SHAW3						.87667	.94791
1	SHAW3	4615.000	9910.000	9593.000	5735.000	1868.000	1316.000	38.000
2	SHAW3	.000097	0	.000044	.000002	.000125	0	.009583
3	SHAW3	0	2400.658	0	0	0	22.153	0
4	SHAW3	141.000	29859.000	11.000	185.000			
5	SHAW3	.001137	.000000	.008310	.000787			
6	SHAW3	0	0	0	0			
0	TYNDALL1						1.00000	1.00000
1	TYNDALL1	4950.000	17085.000	14662.400	18335.000	1733.000	1383.000	62.000
2	TYNDALL1	.000034	.000016	.000022	.000014	.000000	.000476	.000010
3	TYNDALL1	0	0	0	0	0	0	0
4	TYNDALL1	207.000	47156.000	50.000	190.000			
5	TYNDALL1	.000001	.000004	.000010	.000819			
6	TYNDALL1	0	0	0	0			
0	TYNDALL2						1.00000	1.00000
1	TYNDALL2	4368.300	17462.100	14295.800	14740.900	1733.000	1279.000	62.000
2	TYNDALL2	.000047	.000017	.000035	.000000	.000000	.000541	.000010

3	TYNDALL2	0	0	0	0	0	0	0
4	TYNDALL2	207.000	43862.000	52.000	190.000			
5	TYNDALL2	.000001	.000003	.000010	.000855			
6	TYNDALL2	0	0	0	0			
0	TYNDALL3						1.00000	1.00000
1	TYNDALL3	6144.500	17182.200	14806.500	15570.800	1860.000	1438.000	60.000
2	TYNDALL3	.000084	.000000	.000033	.000000	.000061	.000037	.003086
3	TYNDALL3	0	0	0	0	0	0	0
4	TYNDALL3	208.000	47907.000	51.000	188.000			
5	TYNDALL3	.000001	.000000	.000010	.003196			
6	TYNDALL3	0	0	0	0			

Appendix F: Lambda File

1	BERGSTROM1	LUKE3	-.03192
2	BERGSTROM1	DAVIS MON3	.22045
3	BERGSTROM1	BERGSTROM3	.81875
4	BERGSTROM1	MOODY1	.25868
5	BERGSTROM1	SEY JOHN2	-.04214
6	BERGSTROM1	NELLIS1	-.04663
7	BERGSTROM1	HOWARD1	-.00217
8	BERGSTROM1	MOODY2	-.38271
1	BERGSTROM2	MYRTLE B2	-.04002
2	BERGSTROM2	BERGSTROM3	.95292
3	BERGSTROM2	LUKE1	.66141
4	BERGSTROM2	MOODY2	.29833
5	BERGSTROM2	DAVIS MON2	-.11991
6	BERGSTROM2	SEY JOHN2	.03731
7	BERGSTROM2	LUKE2	-.55460
8	BERGSTROM2	MOODY1	-.19451
9	BERGSTROM2	GEORGE3	-.12698
10	BERGSTROM2	M HOME3	.00677
1	CANNON2	HOWARD1	.64705
2	CANNON2	SEY JOHN2	-.03516
3	CANNON2	NELLIS1	.70974
4	CANNON2	HOMESTEAD3	-.73102
5	CANNON2	HOMESTEAD2	.09103
6	CANNON2	LUKE3	-.10330
7	CANNON2	MACDILL3	-.05923
8	CANNON2	MOODY1	.17967
1	CANNON3	NELLIS2	.95212
2	CANNON3	HOWARD1	.78572
3	CANNON3	NELLIS1	-.34992
4	CANNON3	SEY JOHN2	-.15487
5	CANNON3	MOODY1	-.12687
6	CANNON3	DAVIS MON3	-.36389
7	CANNON3	MACDILL3	-.11798
8	CANNON3	MOODY2	.16174

1	ENGLAND1	SEY JOHN2	-.08466
2	ENGLAND1	HOLLOMAN1	.28596
3	ENGLAND1	MOODY1	-.13771
4	ENGLAND1	NELLIS1	.01445
5	ENGLAND1	LUKE3	-.09228
6	ENGLAND1	LANGLEY1	.63421
7	ENGLAND1	DAVIS MON1	-.04082
8	ENGLAND1	DAVIS MON3	-.33854
1	ENGLAND2	DAVIS MON3	-.46773
2	ENGLAND2	SEY JOHN1	2.95747
3	ENGLAND2	HOLLOMAN1	.31279
4	ENGLAND2	MACDILL3	.53210
5	ENGLAND2	NELLIS1	1.14943
6	ENGLAND2	LUKE1	-1.77777
7	ENGLAND2	HOWARD1	-.15182
8	ENGLAND2	SEY JOHN2	-2.33425
9	ENGLAND2	LUKE3	-.12902
1	ENGLAND3	HOLLOMAN1	-.18820
2	ENGLAND3	MACDILL3	.32067
3	ENGLAND3	MOODY1	.79730
4	ENGLAND3	SEY JOHN2	.10496
5	ENGLAND3	GEORGE1	1.36342
6	ENGLAND3	GEORGE3	-.88903
7	ENGLAND3	CANNON1	-.05454
8	ENGLAND3	MOODY2	-.84348
9	ENGLAND3	HOWARD1	.00697
1	HOLLOMAN3	SHAW1	.07597
2	HOLLOMAN3	HOLLOMAN1	.75728
3	HOLLOMAN3	SEY JOHN1	-.21676
4	HOLLOMAN3	DAVIS MON3	.03015
5	HOLLOMAN3	HOWARD1	.16477
6	HOLLOMAN3	SEY JOHN2	.20915
7	HOLLOMAN3	LUKE1	.13176
8	HOLLOMAN3	MACDILL3	-.00094
9	HOLLOMAN3	MOODY2	.45184
10	HOLLOMAN3	MOODY1	-.56387
1	HOMESTEAD1	NELLIS1	.05093
2	HOMESTEAD1	MACDILL1	.03705
3	HOMESTEAD1	HOMESTEAD2	.47089
4	HOMESTEAD1	SEY JOHN2	.24315
5	HOMESTEAD1	HOWARD1	.12559
6	HOMESTEAD1	MACDILL3	.08999
1	HOWARD3	NELLIS1	.19615
2	HOWARD3	HOWARD1	.64446
3	HOWARD3	MOODY1	.34292
4	HOWARD3	GEORGE3	-.25442
5	HOWARD3	BERGSTROM3	-.25695
6	HOWARD3	SEY JOHN2	-.01496
7	HOWARD3	LUKE3	.10689
8	HOWARD3	MACDILL3	.04753
9	HOWARD3	MOODY2	.11658

1	LANGLEY2	MOODY1	-.25564
2	LANGLEY2	DAVIS MON2	-.54598
3	LANGLEY2	LUKE3	3.91750
4	LANGLEY2	DAVIS MON3	.99636
5	LANGLEY2	TYNDALL3	2.08796
6	LANGLEY2	LUKE2	-2.51912
7	LANGLEY2	HOLLOMAN1	.34163
8	LANGLEY2	MACDILL3	-2.11618
9	LANGLEY2	NELLIS1	-.83943
10	LANGLEY2	SEY JOHN2	.36574
1	LANGLEY3	SEY JOHN2	.00831
2	LANGLEY3	HOWARD1	1.82161
3	LANGLEY3	BERGSTROM3	2.52765
4	LANGLEY3	MOODY1	-.73807
5	LANGLEY3	DAVIS MON2	.42330
6	LANGLEY3	M HOME3	.77318
7	LANGLEY3	MOODY2	-2.04088
8	LANGLEY3	HOMESTEAD3	-.61110
9	LANGLEY3	TYNDALL3	-.44933
10	LANGLEY3	LUKE3	-.76681
1	NELLIS3	SEY JOHN2	-.77665
2	NELLIS3	NELLIS1	-1.41864
3	NELLIS3	NELLIS2	2.99213
4	NELLIS3	HOWARD1	.80952
5	NELLIS3	CANNON1	-1.29278
6	NELLIS3	MOODY2	1.26176
7	NELLIS3	DAVIS MON3	-.80873
8	NELLIS3	MACDILL3	.11532
1	SHAW3	HOWARD1	-.21488
2	SHAW3	SEY JOHN3	1.63479
3	SHAW3	GEORGE3	.74479
4	SHAW3	SHAW2	.11387
5	SHAW3	SEY JOHN2	-1.21667
6	SHAW3	MACDILL3	-.19170
7	SHAW3	LUKE3	-.02049
8	SHAW3	SHAW1	-.05340

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